This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

STRAINS IN IRONWORK

HENRY ADAMS.

UC-NRLF
$B 317 002

REESE LIBRARY
OF THE
UNIVERSITY OF CALIFORNIA.
Received June , 1899.
Accession No. 75-971 . Class No.

STRAINS IN IRONWORK.

A COURSE OF

EIGHT ELEMENTARY LECTURES

DELIVERED BEFORE

THE SOCIETY OF ENGINEERS,

IN THEIR HALL, SESSION 1882-3,

BY

HENRY ADAMS,

M. INST. C.E. ; M. INST. M.E. : F.S.I., ETC.

THIRD EDITION.

LIBRARY OF THE UNIVERSITY OF CALIFORNIA

London:
E. & F. N. SPON, LTD., 125 STRAND.
New York:
SPON & CHAMBERLAIN, 12 CORTLANDT STREET.
1898

All rights reserved.

TG
A2
65

75-971

PREFACE.

THE following lectures were delivered during the Session 1882–3, in the Hall of the Society of Engineers, at the request of the Council of the Society, who arranged for several courses of lectures of a character calculated to prove of practical utility to the junior members of the profession, and of which the present formed the first course. They are now published with a view to their being used as an introduction to a more advanced course of lectures which is in contemplation.

CONTENTS.

LECTURE I.

PAGE

Introduction—Varieties and properties of iron—Definitions of load, stress, and strain—Various modes of strain—Popular use of term strain—Breaking weight—Safe load—Factor of safety—Strength of wrought iron, steel, and cast iron—Sectional area—Substitution of letters for words and figures—Formulæ—Leverage—Division into three orders—Principle of each identical—Power, weight, and fulcrum, terms only nominal—Power or active force, weight or passive force—Leverage, simply a question of proportion—Conversion into formulæ—Examples 1

LECTURE II.

Pressure of loaded beams on the supports—Girders and roofs found in same way—Load in centre and out of centre—Parallelogram of forces—Definition and explanation—Composition and resolution of forces—Use in finding effect of load on inclined struts—Horizontal thrust—Combination of parallelograms—Graphic delineation of strains—Leverage by diagrams—Case of similar triangles—Application to pressure of loaded girder on supports—Polygon of forces—Reciprocal diagram—Strain in a strut varies with the angle—Inclined struts—Value of trigonometry—Calculations may be made without it—Horizontal strut—Examples.. 12

LECTURE III.

Distributed load carried on horizontal beam—When inclined, strain varies with angle of bearing surface on support—Lean-to roof—Strain in pair of inclined rafters—Span roof—Tie rod—King bolt—Trussed beam—Strains in same—Strength of girder according to method of fixing and position of load—Cantilevers

PAGE

—Ordinary girders—Continuous girders—Typical form of cross-section of girder—Action of load on a cantilever—Distribution of the strains—Investigation of leverage—Construction of formulæ—Diagram of strains; tension, compression, and shearing—Strain at intermediate points found by ordinates—Examples 21

LECTURE IV.

Effect of distributed load—Strain varies as the ordinates to a parabola—Setting out parabola—Method when particular points only are required—General calculation of strains in a girder divided into three stages: pressure on supports, strain in flanges, strain in web—Girder with concentrated load in any position—Maximum strain immediately under load—Variation of strain between extremities—Investigation by diagrams and formulæ—Also by leverage—Combination of diagrams from two or more loads—Special diagrams for rapid use—Girder with distributed load, method of finding strains—Proportioning material to resist the strains—Examples 30

LECTURE V.

Girder with distributed load, other forms of diagram—Construction of ordinary formulæ—Girders with intermediate supports—Continuous girders—Proportion of spans—Action of load—Points of contrary flexure—Diagram of strains—Formulæ—Humber's Handy Book, recommended for general reference—Moving loads—Moving loads on cast-iron girders—Factor of safety—Formula for cast-iron bridge girders—Strength of beams, ⌊ and T irons—Transverse strains on rafters—Struts, stanchions and columns—Joints and fastenings—Rivets, pins, and bolts—Single or double shear—Examples 39

LECTURE VI.

Open web girders—Warren, lattice, and trellis girders—Angle of inclination of bars—Proportion of depth to length—Warren girder under central concentrated load—Application of parallelogram of forces—All bars equally strained—Strain in flanges

PAGE

cumulative towards the centre of span—Value of strain at each part in terms of x—Vertical ends to girders, how affected by position of last bar—Warren girder under distributed load—Apportioning the load on each span—Action of load from point of application to each support—Bars not equally strained—Strains worked out by parallelogram of forces, commencing at support—Strains on cranes—Ordinary mode of working incorrect—Application of load is diagonally through sheave pin—Angle of jib affects strains—Examples 47

LECTURE VII.

The reciprocal diagram of forces—Explanation of the principle—General knowledge of strains necessary before use can be made of this system—Construction of diagram—Lettering spaces instead of lines—General directions for constructing diagrams—Application to roofs—Diagrams for single and double rafters—For span roof with tie rod—For same with addition of king bolt—For ordinary king-post roof truss—For roof with king and queen rods—For span roof with tie rod and double king bolt—For same with addition of struts—For same having additional ties and struts for larger span—For span roof with king bolt and cambered tie rod—For same with open king bolts—For trussed rafter roof—Examples 55

LECTURE VIII.

Application of reciprocal diagram to lattice girders—Diagram for Warren girder, with central load supported on top flange—For same with load on bottom flange—For same with additional bays—For same with distributed load on top flange—For same with load on bottom flange—For lattice girder, with bars intersecting at 45° under concentrated and distributed loads—For lattice girder with vertical bars—Examples 61

Notes and Errata.

Page 6, line 10 from bottom, *for* Steel 35·50 *read* Mild steel 28·28.
„ „ „ 2 „ *for* Steel 8·12 *read* Mild steel 7·6.
„ 11, „ 7, *for* 15·46 *read* 12·368.
„ „ „ 9, *erase* intensity of.
„ „ „ 12, *erase* intensity of.
„ „ „ 13, *for* 12·19 *read* 10·67.
„ 14, „ 10 from bottom, *after* C *insert w.*
„ 15, „ 6, *for b c read b* C.
„ „ „ 15 from bottom, *for* C W *read* C *w.*
„ 16, „ 10 „ *for* W : P *read w : p.*
„ „ „ 9 „ *for* P : W *read p : w.*
„ 31, „ 16 „ *for* A *c read* A *e.*
„ 32 Note *to follow end of* line 2.—The shearing strain at any point in any girder is equal to the amount of load passing through that point towards the nearest support.
„ 41, last line, *read* $\frac{w a^2}{8 d}$ (*the squaring* 2 *having dropped out in some copies*).
„ 55. Refer to paragraph commencing middle of p. 17 before reading this chapter.
„ 56, line 11 from bottom, *omit* "To make the diagram . . ." &c., to end of paragraph, *and substitute* "The quality of the strain, whether tension or compression, may be found as follows:—On referring to Figs. 27 and 29, Plate 2, it will be seen that the forces meeting at a point will form a closed polygon, having the lines running concurrently, the direction of the arrow-head in the reciprocal figure giving the direction of the force in the force diagram. Applying this principle to Figs. 116 and 117, we know B C in Fig. 116 acts upwards, and starting with B C upwards on Fig. 117 we follow round the closed figure to see the direction of the parts; C A inclined downwards towards the joint and therefore indicating compression; A B horizontal and towards the right, away from the joint in question, and therefore indicating tension."
„ 62, line 9. Note.—The diagram would not have been reversed had the line G H been taken upwards in its proper direction.
„ 63, line 16, *for* P and Q *read* O and N.
„ „ line 5 from bottom, *after* A C *insert*, "because the vertical bars equalise the loading."
„ „ line 4 from bottom, *after* U *add*, Draw A B, W B; then B D, C D; and make D E = A T + ½ T W.

LIBRARY
OF THE
UNIVERSITY

STRAINS IN IRONWORK.

LECTURE I.

Introduction—Varieties and properties of iron—Definitions of load, stress, and strain—Various modes of strain—Popular use of term strain—Breaking weight—Safe load—Factor of safety—Strength of wrought iron, steel, and cast iron—Sectional area—Substitution of letters for words and figures—Formulæ—Leverage—Division into three orders—Principle of each identical—Power, weight, and fulcrum, terms only nominal—Power or active force, weight or passive force—Leverage, simply a question of proportion—Conversion into formulæ—Examples.

In the course of lectures commenced this evening, I shall place before you the subject of Strains in Ironwork in as simple and practical a manner as I am able, assuming that you know nothing of mathematics beyond the first elements of arithmetic, and I shall endeavour, without going higher than the rules of simple proportion, to make clear to you all you require to learn in order to determine the amount of stress in the different parts of a structure, from a simple bolt or rivet to the complete framing of some of the gigantic works in iron now called for by modern engineering. The importance of this study cannot be overrated, whether we consider the Civil Engineer and the Architect who give the first conception of the structure, the Draughtsman who works out the detail of the design, or the Mechanical Engineer and Con-

tractor who carry it into practice; everyone who has to do with either the design or the execution must have a more or less complete knowledge of the stresses and strains, in order that his portion of the work may be successfully carried out. The want of this knowledge is often apparent in the works of Architects: the use of iron is comparatively new to them, although now indispensable, and they are too often satisfied to leave the contractor to ascertain the necessary amount of material: a practice which, there is little doubt, has sometimes led to disastrous results; but as the contractor is paid by weight, the error is generally on the safe side.

A knowledge of the physical properties of iron, and the mechanical details of its formation into members and structures, form of course a large part of the stock-in-trade in designing, but the "calculation of strains" as it is called must be looked upon as certainly the most important item. This tells you what amount of stress must be provided against in the various parts, but it does not tell how to proportion the shape of the parts. It clothes a skeleton of the structure with figures representing the forces to be resisted, and undertakes all the theoretical portion of the work, preparing it for the practical designer, who, in place of the figures, draws in the breadth and thickness of the parts.

It will be necessary briefly to call your attention to a few facts connected with the material, in order that you may appreciate the different forms we shall investigate.

Iron is known under three principal varieties: wrought iron, steel, and cast iron; and, strange as it may seem, the only essential difference between these three varieties is the amount of charcoal or carbon combined with the iron. The purest is WROUGHT IRON, it contains not more than $\frac{1}{4}$ lb. of carbon in 100 lbs. of iron. It is *malleable*, can be forged or hammered into various shapes at a red heat. It is *ductile*, can be rolled into plates and bars, drawn into rods of different sizes and even into fine wire. It is *weldable*, pieces can be

joined together at a white heat by hammering them, making one solid piece equally strong throughout. It is *soft*, considered as a metal, and *fibrous* or stringy with a grain somewhat after the nature of wood, running in the direction of its length. It is *tough* and *elastic*. It rapidly *oxidises* or rusts in damp climates, if unprotected by paint or otherwise.

STEEL is wrought iron with a little more carbon in it, say 1 lb. in 100 lbs. of iron, but this slight addition of carbon makes a vast difference in many of its properties. There are other alleged constituents in steel, but the evidence is incomplete, and need not trouble us at present. The proportion of carbon also varies, steel beginning where wrought iron leaves off; in fact, the line of demarcation is so slight, that there are often samples of metal which one man will call iron and another steel, even after an elaborate chemical analysis. Steel is *malleable* and *ductile*, but requires more care in working than wrought iron, and a lower temperature. It is *weldable* if the carbon is not present in too great a proportion, but when the carbon is in excess the steel can be melted and run into moulds like cast iron. The special and significant property of steel is its ability to *temper*, as it is called, or take various degrees of hardness, when made red hot and plunged into water, which neither wrought nor cast iron will do. Its texture varies from *fibrous* to *crystalline* or granular. It is much *tougher* than wrought iron, and more *elastic*, and generally speaking, it would be described as *stronger*.

CAST IRON is wrought iron with a large admixture of carbon, say 2 to 5 lbs. in 100 lbs. of iron. It is *brittle*, *inflexible*, and *crystalline*, neither malleable nor ductile, cannot be welded, but it may be *melted* at a high temperature and poured into *moulds* or impressions in sand, forming *castings* of the shape required.

As you might anticipate from this description, one form of iron may be changed into another by the addition or sub-

traction of carbon; and this is actually done, but the method and object do not concern us just now. There are a few intermediate and allied stages which may be noticed; for instance, wrought iron may have the surface converted into steel, called *case-hardening*, in order to give a rubbing surface of steel without incurring the expense of steel for the whole piece. Cast iron may have the surface hardened or *chilled* in the process of casting; this is done where a very hard surface is required to resist the wear and tear, the piece not being subject to much strain. Cast iron is sometimes partially converted into wrought iron, when it is required to be tougher than the ordinary cast iron, but cheaper than forged wrought iron: this is called *malleable cast iron*. Malleable iron and rolled iron are only other names for ordinary wrought iron. *Mild steel* is only one remove from wrought iron, it has all the properties of steel but very slightly or mildly. Cast iron is sometimes spoken of only as *metal;* at other times the term metal is used for brass and gun metal; and again, it is used in speaking of the dimensions in the same way as the word scantling. The chief and distinctive terms to be used are—wrought iron, steel, and cast iron.

There are two principal varieties of fastenings adopted in connection with ironwork, viz., bolts and rivets. Bolts are pieces of round iron with a solid head at one end and a loose nut screwed on at the other. Rivets are also pieces of round iron with a solid head at one end, but they are plain at the other end. When used the rivet is made red hot, put through the pieces to be joined, and held firmly, while another head is formed by hammering the point down. On account of the hammering required, riveting is not suitable for cast-iron structures, as the metal is too brittle to withstand the shocks; it is fortunately not much wanted, however, as castings may be made very large and require few joints. Wrought iron is mostly riveted, as it is a cheap and permanent mode of connecting the parts, but no rivets are used larger than one inch

diameter in ordinary work; when such would be required, bolts are resorted to. Instead of having two or three bolts or rivets to connect a joint, the connection is sometimes made by pins or cotters, a single pin being often three or four inches diameter. The pin when used alone allows of some movement, or "hinge-like" play in the joint, which is in some cases desirable.

The strength of any piece subject to direct strain depends upon the size or sectional area of its smallest part, and in a whole structure the strength is similarly measured by that of its weakest part. Roughly speaking, we may say that twice the size gives twice the strength, but there are important modifications of the rule, which we shall observe in due course. The art of designing economically consists in providing the maximum of strength with the minimum of material, and there would be no scope in this respect if the size alone determined the strength.

There are three terms used in such discussions as the present, which I think it necessary to direct your careful attention to. They are—*load*, *strain*, and *stress*. By a LOAD on any member of a structure is meant the aggregate of all the external forces acting upon it, including the weight of the member itself, and of other parts supported by it. By a STRAIN is meant the change of form produced in a piece by the action of a load; and by a STRESS is meant the resistance set up in the material, by its molecular forces opposing the action of a *load* in producing a *strain*. Stress and strength may be looked upon as synonymous terms, although they are not used exactly alike. Thus the *strength* of a piece in a given position may be such, that a *load* of so many *lbs.* produces a *stress* of so-many *lbs. per square inch*, the result being a *strain*, or change of form of a certain amount, whether temporary or permanent, and, when large enough, appearing as stretching, shortening, bending, crumpling, or twisting. The term strain is commonly used instead of stress, and is usually meant as

such when we speak of the calculation of strains; so that although we may use this term as an ordinary office phrase, we must bear in mind the distinction when we make a systematic study of the subject.

The various kinds of strain which can come upon any member of a structure are:

TENSION: stretching, pulling, tearing.

COMPRESSION: crushing, pushing, squeezing.

TRANSVERSE STRAIN: cross strain, bending, deflection.

TORSION: twisting, wrenching.

SHEARING: cutting, nipping; or, when acting along the grain of wood, it is called DETRUSION.

BUCKLING, or crumpling, is a compound strain made up of crushing and bending. Transverse strain may be resolved into tension and compression; and Torsion belongs almost exclusively to machinery. Shearing may generally be taken as equal in amount to tensile strength, and we have then Tension and Compression left, as two chief strains of opposite character, and upon which the others may be said to depend. Now, taking these two strains, we find that the stress per square inch sectional area sufficient to rupture the material when of ordinary quality is as follows:

	Tension.	Compression.
Wrought iron ..	22 tons	18 tons
Steel	35 „	50 „
Cast iron	7 „	42 „

The safe load on a structure is usually taken at $\frac{1}{4}$th the breaking weight, $\frac{1}{4}$th being in that case called the factor of safety, and thus we find that we may safely put the following stresses per square inch sectional area upon the material:

	Tension.	Compression.
Wrought iron ..	5 tons	4 tons
Steel	8 „	12 „
Cast iron	1½ „	7 „

These are all within ¼ of the ultimate strength, the cast iron being from ⅓ to ⅛ on account of the irregularities in that material. These must be taken as general or approximate figures, and for dead or gradually applied loads only; as we shall find, in considering special structures, there are specially recognised stresses allowed under the ordinary working loads. Greater loads than these might be applied without endangering a structure, if we could ensure both material and workmanship being thoroughly sound, but unfortunately this cannot be done. If the material be strained to within ⅓ of its breaking weight it is liable to permanent injury, the atoms being, as it were, pulled so far apart that they cannot get back into their proper places again.

You will observe that wrought iron has nearly the same strength in tension and compression, while cast iron has nearly six times the strength in compression that it has in tension; and hence, in some structures, cast iron is used for the parts in compression, and wrought iron for those in tension.

Now I must go into figures, and those of you who have already some knowledge of the subject must bear with me while I explain to those who are quite beginners, how sectional areas are found. To find the sectional area of a flat or square bar, multiply the breadth by the thickness, and the measurements being taken in inches, the result will be square inches area. For the sectional area of a round bar multiply the diameter by itself and then by 11, and divide by 14. But we can put this into a sort of shorthand, very compact and useful:

Square bar $a = b \times t$
Round „ $a = d \times d \times \frac{11}{14}$, or $d^2 \times \cdot 7854$.

These are formulæ or equations, and the system of putting down letters, instead of figures or descriptions, is neither more nor less than Algebra. If you were to see the section

of an angle iron for the first time, you would doubtless think it a very difficult matter to obtain the sectional area by measurement; so it is, to get it exactly, but it is an easy matter to obtain it approximately. You will see (Fig. 1) that it is curved at the edges and the root, and tapered along the sides; but a straight line parallel with the back, cutting the centre of the tapered side, would give very nearly the same amount of material, and this is how the measurement is taken (Fig. 2), $a = \overline{b \times t} + \overline{(b - t) \times t}$.

Tee iron, channel iron, and cross iron are found in a similar manner. Hollow columns are found by deducting the area of the interior from the area of the exterior, each being found in the way shown for round bars.

We come now to the consideration of a few important principles in Mechanics which must be mastered before we go further. The first of these is the lever. Levers are divided into three orders, according to the relative position of the *power* or active force, the *weight* or passive force or resistance, and the *fulcrum* or pivot round which movement takes place, or tends to take place, thus:

1st order.	Fulcrum	between	the others	(Fig. 3).
2nd order.	Weight	„	„	(Fig. 4).
3rd order.	Power	„	„	(Fig. 5).

But in each of these arrangements there is only one principle involved, and as this is most clearly shown in a lever of the first order, we will take that for investigation. The *lever* is assumed to be a rigid, inflexible body without weight. The *fulcrum* is situated at any point between the two extremities, the *power* is the force or load applied at one end, and the *weight* is the resistance or load at the other end. The lever may be curved or straight, but if curved we take our measurements of its length in a straight line only, measuring from the points of application of the power and fulcrum for the *leverage of the power*, and from the points of

application of the weight and fulcrum for the *leverage of the weight*. The lever may even be assumed to be bent at right angles, the fulcrum being at the angle, but our measurements will be taken in the same way, and there will be no difference in its value as a mechanical power in that respect, provided that the forces are at right angles to each portion of the lever (Fig. 6); but if the forces are not at right angles to the lever, we must take for the true leverage distance a measurement at right angles to the direction of each force, as *ab*, *bc* (Fig. 7). The distance from the power to the fulcrum, as defined in these examples, multiplied by the power, is called the *moment of the power*, and the distance from the weight to the fulcrum multiplied by the weight is called the *moment of the weight*. When these moments are equal the lever balances, but if one be in excess of the other the lever will move until it reaches a position in which it will balance, or until it is stopped by some external object. Suppose the weight to be taken away and the lever prevented from moving by contact with some fixed object, then the pressure against this object will be the same in amount as that of the weight removed. The power may be represented by muscular force or by any external pressure or load, and the weight by any resistance either external or internal. If we call the power P, its leverage x, the weight W, and its leverage y, we can represent the relationship clearly thus:

$$P \times x = W \times y$$

which is called an equation, or the same thing may be explained by "rule of three," thus:

$$P : W :: y : x;$$

and you know that in a proportion sum you multiply the second term by the third and divide by the first in order to get the fourth, thus:

$$\frac{W \times y}{P} = x;$$

but if we have any three of the four given, we can find the remaining one in the same way, thus:

$$\frac{P \times x}{W} = y. \quad \frac{P \times x}{y} = W. \quad \frac{W \times y}{x} = P;$$

and, putting the respective loads in *lbs.*, with their distances in *inches*, in place of these letters, we can obtain the arithmetical result in any given case. Suppose, for instance, we have a case in which the power is 8 lbs., its leverage 12 inches, and the leverage on the other side 10 inches (Fig. 8). Taking $W = \frac{P \times x}{y}$, we have $W = \frac{8 \times 12}{10}$, therefore $W = 9\frac{6}{10}$, or in decimals, 9·6 lbs. as the pressure caused against any resistance, or the amount of actual weight it would support. Exactly the same rules and lettering will apply to the other orders of leverage, and we need not, therefore, take them in detail. There is only one point about which I must caution you particularly, and that is, to take in each case the *full distance to the fulcrum*, which is a point sometimes overlooked in levers of the 2nd and 3rd kinds.

In these calculations the lever is assumed to be a rigid, inflexible bar without weight. The weight of the lever will of course affect the result in any practical case, but by omitting it for the present, the principles will be much easier to understand. To sum up these principles, the product of a force into the perpendicular distance of its direction from any given point is termed the moment of the force about that point. And, taking the power, weight, and resistance at fulcrum, as three pressures by which the lever is kept at rest, the two terminal pressures must always act in the same direction, while the intermediate pressure acts in the opposite direction; the intermediate pressure must always equal the sum of the other two; and, lastly, when equilibrium obtains, the moment of the power about the fulcrum must be equal to the moment of the weight.

QUESTIONS FOR HOME-WORK.

Answers to be given up at next Lecture.

1. Required the breaking weight of a wrought-iron bar $1\frac{1}{2}$ inches by $\frac{1}{2}$ inch, having a load hanging to it. (Ultimate tensile stress.)—Ans. 16·5 tons.

2. Breaking weight of a steel rod $\frac{3}{4}$ inch diameter, with a hanging load?—Ans. ~~15·46~~ tons. 12.36

3. Safe load on two wrought-iron plates, containing together 9 square inches, and being under direct thrust. (Safe working ~~intensity of~~ stress in compression)?—Ans. 36 tons.

4. Safe load on three steel bars taken together, each being $1\frac{1}{2}$ inch by $\frac{1}{16}$ inch, and acting as ties. (Safe working ~~intensity of~~ stress in tension)?—Ans. ~~12·19~~ tons. 10.67

5. Safe load on a hollow cylindrical piece of cast iron, 4 inches inside diameter, 6 inches outside diameter?—Ans. 109·96 tons.

6. What sectional area in wrought iron would be required to resist a compressive load of 15·25 tons safely, assuming the piece to be too short to bend under the strain?—Ans. 3·82 square inches.

7. If you assume cast iron to require a factor of safety of $\frac{1}{10}$, what tensile stress could you put upon a piece $7\frac{1}{2}$ inches by $\frac{1}{2}$ inch?—Ans. 4·6 tons.

8. A bar 3 feet 6 inches long, supported at 1 foot 6 inches from one end, has a weight of 18 lbs. hanging on the long end; what pressure will be required at the short end to balance it?—Ans. 24 lbs.

9. A bar 6 feet long is pivoted at one end; what power would be necessary at 1 foot from the free end, to balance a weight of 23 lbs. at 1 foot from the pivot end?—Ans. 4·6 lbs.

10. A bar 4 feet 3 inches long is hinged at one end, it is pushed perpendicularly at a point 1 foot $3\frac{1}{2}$ inches from the free end by a force of 29 cwts.; what pressure will the bar exert against a resistance at the free end?—Ans. 20·19 cwts.

LECTURE II.

Pressure of loaded beams on the supports—Girders and roofs found in same way—Load in centre and out of centre—Parallelogram of forces—Definition and explanation—Composition and resolution of forces—Use in finding effect of load on inclined struts—Horizontal thrust—Combination of parallelograms—Graphic delineation of strains—Leverage by diagrams—Case of similar triangles—Application to pressure of loaded girder on supports—Polygon of forces—Reciprocal diagram—Strain in a strut varies with the angle—Inclined struts—Value of trigonometry—Calculations may be made without it—Horizontal strut—Examples.

We now come to the application of some of the principles we learnt in the first lecture. We will commence with an ordinary girder, finding by leverage what pressure or load is caused upon the wall supporting it. The arrangement will be as shown in Fig. 9, forming virtually a lever of the second or third kind, although it has apparently two fulcrums and no power; but you must bear in mind that these are accidental terms only, and that whether we call any given load a power or a weight, it makes no difference in the result.

First, let us assume the load to be exactly in the centre; it would appear on inspection that the pressure upon each support would be $\frac{1}{2}$ the load $+$ $\frac{1}{2}$ the weight of the girder, and this can be proved to be correct; but if the weight be not exactly in the centre, the pressure will evidently be greater on the nearer support, and in order to find out how much greater, we must make use of our formula for leverage. Here let A be taken as the *fulcrum*, W as the active load or *power*, and B as the passive resistance or *weight*, x the distance of the load from the left-hand support, and l the total distance between the supports, called the span of the girder. Then

the leverage of the power will be x, the leverage of the resistance l, and the pressure on $B = \frac{W x}{l}$. For the pressure on A, we must assume B as the fulcrum, and A the resistance, then the leverage of W will be $l - x$ (i. e. the length of l, less the length of x), and the formula will stand thus:

$$\text{Pressure on A} = \frac{W \times (l - x)}{l};$$

but to each of these answers, *wherever the load may be*, we must add half the weight of the girder, supposing it to be of uniform section, to get the total load on the supports. The proof that the pressure on the supports is equal when the load is in the centre is obtained thus:—When W is in the centre $l - x = x$, and we may therefore put x in place of $l - x$ in the last formula, when it becomes identical with, and therefore equal to, the preceding formula.

If you understand the work so far as we have gone, you have really learnt a great deal; because all girders, roofs, and bridges tied together into one frame follow exactly the same rules. Thus, if this outline (Fig. 10) be taken as representing one truss of a roof, say twenty feet span, and the weight of itself with the covering it supports, including allowance for wind and snow = 5 tons, then the pressure on each support will be $2\frac{1}{2}$ tons. Or, if we take a rigid frame irregularly shaped or loaded, as in Fig. 11, or a lattice girder, Fig. 12, the proportion of the load on each support (apart from weight of girder) will be determined by the formulæ we have just taken.

Now, leaving the question of leverage, we must take up another of the fundamental principles, called the *parallelogram of forces*. A parallelogram is simply a four-sided figure with its opposite sides parallel, Figs. 13 to 16. The principle of the parallelogram of forces is this:—If two adjacent sides of a parallelogram represent by their position

and length the direction and magnitude of two forces, then a diagonal from the junction of these two lines will represent the direction and magnitude of a single force which would have the same effect as the two others combined.

The reverse of this is equally true:—If a force be represented in magnitude and direction by the diagonal of a parallelogram, the two adjacent sides meeting at one end of that diagonal will represent the magnitude and direction of two forces giving a similar result. But the same diagonal would answer for any number of parallelograms, as in Fig. 17, and we can therefore take the most convenient one; for instance, if we have a force acting in the direction A B, Fig. 18, and we wish to substitute for this two other forces, one of which shall be in direction and magnitude equal to A C, then we join C B, make A D parallel to C B, and B D parallel to C A, then A D will be the second force required. Or we may have the force A B, Fig. 18, and have the *directions* of the forces A C A D, but not their magnitude; in that case, by drawing lines parallel to A C, A D, through point B, we obtain their magnitudes.

Now let us apply this knowledge to the case of two inclined struts, thus (Fig. 19), A C and C B, the load upon them being represented by W. Here we have a single force, the load, of given direction and magnitude, and we have the directions of two other forces, or the lines in which they will act, and we want to find their magnitudes. If we mark off on C W a point w, so that C w equals the load to any given scale, and through w draw lines $w\ a$, $w\ b$, parallel to B C, A C, then the lengths C a, C b, will give the respective magnitudes of the forces in C A, C B.

It is clear that these will be pushing forces in the struts, or in other words, the struts will be in compression, and therefore some resistance must be provided to hold their lower ends. We have shown them resting on a wall, and now we must ascertain what the effect is. Here we come to a repetition of the operation we have just performed. We

have, taking one side first, the one force acting in line with the strut to be resolved into two, one acting downwards and giving, as we may say, the weight on the wall, and the other acting horizontally, or tending to cause the foot to slide along the wall, called the horizontal thrust. Mark off from B, B $d = b$C, which is the measure of the inclined thrust in the rafter, then draw $d\,e$ vertical, and $d\,f$ horizontal, continue the surface of the wall through B to e and the side of the wall also through B to f, then B e will represent the horizontal thrust, and B f the downward thrust or weight. The downward thrust is of course provided for by the wall, but the horizontal thrust must be counteracted by tying the feet of the struts together, or by bolting them down, unless the bearing surface of the wall be cut away perpendicular to the strut, as in Fig. 20, in which case the thrust and weight would balance each other. Exactly the same description would apply throughout, if the struts were of *different lengths*, the operations being repeated on each side, and the strains being found to be smaller on the side with the flatter angle. Instead of having a separate parallelogram for the foot of the strut, we may combine it with the first one drawn, thus (Fig. 21), and I will take unequal struts this time. C w being set off equal to the weight, $w\,a$ drawn parallel to B C, and $w\,b$ parallel to A C, then a C will be the compression in A C, $a\,c$ the horizontal thrust at A, C c the downward thrust at A, C b the compression in C B, $d\,b$ the horizontal thrust at B, and C d the downward thrust at B.

By comparing this diagram with the preceding one, you will see that this is worked on the same principle, but is more compact. Instead of C b being repeated at the lower end of the strut, it remains at the upper end, and the thrust is resolved by drawing the horizontal and vertical lines from b and C.

In the case of leverage I took the algebraic method of calculation, and in the parallelogram of forces the geometrical method, but they can both be worked out either

way. In any system by which forces or stresses are indicated by the lengths of certain lines, the method is known as "the graphic delineation of strains." If you accustom yourselves to this mode of working, you will be astonished at the number of cases in which it will assist you, and the ease with which complicated questions may be worked out.

It may be useful just to show you how questions of leverage may be worked out with a ruler and pencil. In a lever of the first order we have the arrangement shown in Fig. 22. Over the fulcrum set up *w* equal in length to the known weight, upon any given scale; join the end of this line with the power end of the lever, from the fulcrum draw a line parallel to the last, and produce a line over the weight to meet it, call this line *p*. Then, if *w* represent the weight to be balanced on this lever, *p* represents the power that will do it; and *vice versa*, if we have a given power and want to find the weight it will balance, we set up *p* equal to the power and join it to the fulcrum, from power end of lever draw line parallel, then draw vertical line over fulcrum to meet the last, and it will equal W. This method depends upon the properties of similar triangles, or those of different sizes but similar shape. For a full explanation you must refer to Euclid VI. 2, but it is easy to see that it is simply a question of proportion in the triangles:

$$x : y :: w : p$$

or,

$$y : x :: p : w.$$

In levers of the second and third orders, the graphic constructions will be alike, as seen in Figs. 23 and 24.

Set up *w* over P, equal to the weight (Fig. 23), then line *p* drawn above the weight will equal the power required; and set up *p* over W, equal to the power (Fig. 24), then line *w*, drawn under the power P, will represent the weight that will be balanced.

In representing the pressure of a girder upon its supports

the principle is the same, although the diagram looks rather different. We will take an example, see Fig. 25. Let A B represent the girder whose length is l, and W the load, its position dividing the girder into two portions x and y. Take line A B as a base line, and at each end set up a line w equal to the load W. Then for the load upon bearing A, join point B with the top of line w over A, and through a point on the base line vertically under the W draw a parallel line; the included space a on line w over A, shown thick in the diagram, will then be the proportion of the load borne at A. By reversing the construction and drawing the parallel lines to the right, we get in the same way the portion b representing the load upon B;

then $l : x :: w : b$
and $l : y :: w : a$.

Before we leave the geometrical system for a time I must call your attention to a remarkable property connected with the graphic representation of *forces in equilibrium*. By equilibrium we mean, in plain English, that whatever strain may be on the different parts, there is no tendency to move unless something gives way. The property is this: if the forces be represented by lines of similar direction and proportional magnitude, they will form, if put together as a continuous outline, a closed figure of as many sides as there are forces: thus, if Fig. 26 represent three forces in equilibrium, the lines put together will make Fig. 27, called a *triangle of forces*; or if there are more than three forces, as in Fig. 28, the lines put together will make Fig. 29, called a *polygon of forces*. If the lines be drawn at the proper angle and of the right length, but do not form a closed figure, then we know for a certainty that the forces are not in equilibrium, and that we have over estimated—or under estimated—one or more of them, and hence this mode of re-arranging the lines forms a valuable check upon accuracy of the work. The

converse of the polygon of forces is equally true, viz.: *If* the sides of any closed figure be taken to represent the directions of the same number of forces, taken in order, and meeting in a point, then the lengths of the sides will represent the magnitudes of the forces. This is an exceedingly useful property, and we shall find that it enables us, by means of what is called a "Reciprocal diagram," to ascertain easily the strains upon a complicated framework.

We have seen how to find the strains on inclined struts geometrically; it is also desirable to know how to find the same by calculation. It is evident that if the strut were vertical, the strain would be exactly equal to the load; while if it were horizontal, there would be no strain at all (the end not being fixed), the difference between these two extremes depending upon the angle of the strut. If, however, we make our calculations from the angle itself, we shall have to use trigonometry, which means three-angle measurement; but we can avoid this by calculating from the parts which form the angle, viz., the height and the span.

Let C D, Fig. 30, represent the proportion of weight borne by the strut C B, then the length C B will represent the compressive strain in C B. The calculation is very simple. Let us mark the perpendicular height C D = P, the inclined length C B or hypothenuse of triangle B D C = H, and the horizontal distance B D or base of triangle = B, w = proportion of load borne by strut C B as found by leverage, t = horizontal thrust at foot, d = downward thrust, and s = inclined thrust or strain in the strut or rafter; then,

$$\mathrm{P} : w :: \mathrm{H} : s, \text{ or } s = \frac{w\,\mathrm{H}}{\mathrm{P}}$$

$$\mathrm{P} : w :: \mathrm{B} : t, \text{ or } t = \frac{w\,\mathrm{B}}{\mathrm{P}}$$

$$\mathrm{H} : s :: \mathrm{P} : d, \text{ or } d = \frac{s\,\mathrm{P}}{\mathrm{H}}.$$

These simple formulæ being due to the fact that the length of the sides represents proportionally the strain in each.

If out of three dimensions—base, perpendicular, and hypothenuse—you have only two given in figures, you can measure the third off to scale, which is quite near enough for ordinary purposes; but if you should wish to have mathematical accuracy, the following will be the formulæ:—

$$B = \sqrt{H^2 - P^2}, \quad P = \sqrt{H^2 - B^2}, \quad H = \sqrt{B^2 + P^2}$$

depending upon Euclid I. 47.

Now suppose one of the struts to be inclined and one horizontal, as in Fig. 31, the horizontal strut will have no direct strain from the load, but it will have a great strain due to supporting the end of the inclined strut. A parallelogram with C w = full load, according to any given scale, will give us at once C a = strain in C A, and C b strain in C B.

By calculation the strain in A C $= \frac{B\ W}{P}$, and that in C B $= \frac{H\ W}{P}$.

In all these illustrations we have omitted the weight of the parts, because it would unnecessarily complicate the questions until we have taken up distributed loads, which we shall do in the next lecture.

QUESTIONS FOR HOME-WORK.

1. A girder 24 feet long, with a span of 20 feet, has a load of 9 tons 3 feet away from the centre; what will be the pressure on the nearest support, omitting the weight of the girder?—Ans. 5·85 tons.

2. A lattice girder weighing 1 ton carries a uniformly distributed load of 13 tons over a span of 11 feet; what proportion of the total load will be borne by each of the supports?—Ans. One half on each = 7 tons.

3. An inclined rafter 8 feet long rests against another 15 feet long, and the lower ends are supported on a level surface; show the amount

and direction of the various strains set up when a load of 9 tons is carried at the apex, and the feet are 18 feet apart?—Ans. See Fig. 32.

4. A cast-iron girder 17 feet 3 inches span has a load of $7\frac{3}{4}$ tons resting at a point 5 feet 9 inches from support A; what will be the load on support B?—Ans. 2·58 tons.

5. The upper end of a rafter inclined at an angle of 45° rests against a horizontal strut; what weight must be hung at the junction to balance an upward force of 2 tons acting along the inclined rafter?—Ans. $\sqrt{2} = 1{\cdot}414$ tons.

6. In the last question, if the rafter were placed at a steeper angle with the same load, would the strain in it be greater or less?—Ans. Less.

7. Two forces of 10 and 15 tons respectively act upon a point at right angles to each other; if the direction of the smaller force should be altered to 120° from the greater, what must be their magnitude to produce the same resultant as before?—Ans. 11·55 and 20·77 tons.

LECTURE III.

Distributed load carried on horizontal beam—When inclined, strain varies with angle of bearing surface on support—Lean-to roof—Strain in pair of inclined rafters—Span roof—Tie rod—King bolt—Trussed beam—Strains in same—Strength of girder according to method of fixing and position of load—Cantilevers—Ordinary girders—Continuous girders—Typical form of cross-section of girder—Action of load on a cantilever—Distribution of the strains—Investigation of leverage—Construction of formulæ—Diagram of strains; tension, compression, and shearing—Strain at intermediate points found by ordinates—Examples.

We have, so far, considered the effect of concentrated loads only; if we had assumed the loads to be spread over the surface, or distributed, it would have modified some of the results. These cases require careful attention, because they nearly always involve more difficulty than concentrated loads. Let us take an easy one first—an ordinary girder or horizontal beam, as in Fig. 33. As it stands, each support would bear half the full load, but if the beam were inclined what would be the result? It will vary according to the nature of the bearing at the higher end, A, Fig. 34; suppose we can secure a horizontal bearing, as in Fig. 35, then the load will be supported half at A and half at B, each half resting on the support, and acting as downward thrust or weight, without putting any compression on the rafter, or thrust at the foot. There will of course be a cross strain, tending to break the rafter by bending, but that is a matter for separate consideration. If the higher support were placed vertical instead of horizontal, as in Fig. 36, then point A would get no direct support, and there would be the same pressure against the wall as if it were

a horizontal strut. Taking for weight the half of the lead that ought to be supported at A, the effect of this half is transmitted down the rafter to B, where it is resolved into a downward thrust and a horizontal thrust, as in Figs. 30 and 31. It will be found that this downward thrust is just equal to half the total load, while the other half is resting direct upon B; therefore B gets the whole load upon it, besides the portion found as horizontal thrust, which will just equal the thrust found upon the vertical wall. This is the condition of things in the simplest form of roof, viz. a lean-to, and an intelligent carpenter will always give a horizontal bearing like Fig. 35, to prevent any outward thrust, although it is not at all unusual to find it omitted. If instead of the vertical wall we add another rafter, inclined the opposite way, we shall have the conditions of a common span roof or pent roof, as in Fig. 37. Here we have each rafter supporting $\frac{1}{2}$ the load, say $\frac{1}{4}$ resting at the lower ends, and $\frac{1}{4}$ at the upper ends, the $\frac{2}{4}$ at the upper ends reacting against each other, causing compressive strains in the rafters, which will be resolved at A and B into thrust and weight as before. The $\frac{1}{4}$ at each lower end is simply dead weight on the supports; and it is most important to observe that, omitting the cross strain, no effect whatever is produced by it upon the rafters. The thrust from a roof of this kind frequently causes the supports to be pushed over, and hence it is only used for small sheds and greenhouses. The thrust may be met by tying the ends of the rafters together, as in Fig. 38. This tie rod will be in tension because the ends tend to be forced asunder. The amount of strain will equal the thrust found *on either side*, not the two thrusts added together, because they are acting in opposite directions. An illustration would be, two men pulling at a rope in opposite directions; although two men would be pulling, there would only be what might be called a one-man strain in the rope, because the other man might be replaced by a dead post.

In this sketch we have the simplest form of roof truss, but there is a practical defect in it, apart from decreasing the head-room for walking underneath. You know that it is impossible to pull a chain or string to a perfectly straight line: it bends down in the middle, however hard it may be pulled; this bending is called sagging, and to prevent the sagging of the tie rod in the example before you a king bolt is often put in, as in Fig. 39, to hold it up in the middle. In calculating the strains on this as a roof truss, you will find no strain on the king bolt due to the load on the roof; all it has to do is to bear a portion of the weight of the tie rod; we are, however, for the present, omitting all strains due to the weight of the parts, and also the effect of cross strains.

If we reverse the last example, as in Fig. 40, we have the simplest form of a trussed girder or bridge; it will be familiar to you as the method of strengthening a beam of timber for carrying loads. In this arrangement all the strains are reversed: we have C D now acting as a strut in compression, and A D, D B, as ties in tension, A B being in compression. Suppose we had a load distributed over the beam, there would be one half on A C, and the other half on C B. The half on A C would be resting half of it on A, and half on C; while that on C B would be resting half on C, and half on B; so that we should have $\frac{1}{4}$ the full load on A, $\frac{2}{4}$ on C, and $\frac{1}{4}$ on B. The portions at A and B would rest direct upon the support, without causing any strain to pass through the framing, but the $\frac{2}{4}$ on C would be transmitted through C D, and thence through D A, D B, to A and B; because, whatever the arrangement of trussing, the final result comes to the abutments or supports. C D being exactly in the direction of the load on C, that load, viz. $\frac{1}{2}$ the total load, will be the measure of the strain on C D without requiring any calculation. By drawing the parallelogram shown in Fig. 41, the load *c* D will be resolved into

two forces, D *a*, D *b*, giving the tensional strains in D A, D B. Then by joining *a b* we resolve the force *a* D into *a o*, *o* D, and *b* D into *b o*, *o* D, the horizontal lines *a o* or *o b* giving the compression in A C B; and the vertical line *o* D, the weight on A and B, in addition to the portion of the load which we found resting there direct.

We might continue to take other forms of trussing, more and more complex, and work them out in the same way, but before we proceed further in this direction it will be necessary for us to learn something of the effect of cross strains, such as occur in girders.

The effect of the load upon a girder, or any piece of a structure subject to cross strain, varies considerably, according to the manner in which the girder is supported and the nature of the load. I might give you a tabulated statement of this, but it will be better to work it out and show you the reason of these differences.

First take a girder having one end built into a wall, or otherwise firmly fixed, as in Fig. 42, and called in this position a cantilever; or the projecting end of a girder beyond a column would be a similar case. Suppose this girder to be 12 feet long, and just strong enough to bear a load of 1 ton on the end; then if the load be distributed, as in Fig. 43, it will bear 2 tons, because one half will be carried direct by the support, and the other half or 1 ton will be carried by the end of the cantilever as before. Or we may look at it another way, and say that if the load were collected at the centre of gravity it would have a leverage of only half the amount, the moment of 2 tons at 6 feet being equal to the moment of 1 ton at 12 feet, and therefore of corresponding effect as regards the maximum strain occasioned in the girder, although we shall find further on that the detailed effect differs.

Now, if we can support the ends of the girder, leaving the same clear span as before, and put a concentrated load in

the middle (Fig. 44) it will bear 4 tons, because we may say 2 tons is on the middle end of each half of the girder, and as the half girder is only half the span or leverage of the previous example, the cantilever, it will bear double the load with the same strain. If the load be spread over the girder as in Fig. 45, it will carry 8 tons; we may say 4 tons is on each half of the girder—2 tons on the supports direct, and 2 tons on each side at the centre—equivalent to the previous 4 tons in the centre. If both ends of the girder be built into a wall for some distance, or otherwise firmly secured at the ends, as in Fig. 46, we may put 8 tons in the centre. We may look upon this as two cantilevers, each of one-fourth the span of our former one, and supporting at their ends a girder of half the span, as in Fig. 47. The cantilevers being one-fourth the span will each carry 4 times the load ($1 \times 4 = 4$, $4 \times 2 = 8$ tons). But suppose the load to be distributed, this girder will presumably carry 16 tons, because half will be carried by the walls direct, the other half straining the girder as before. Professor Unwin says that a girder under these conditions would only carry 12 tons; Dr. Anderson says it is a doubtful case, and that different authorities give from 12 to 16 tons: so that we may look upon 12 tons as the minimum to allow, and 16 as the maximum. Taking the latter figure, and reviewing our illustrations, we find that similar girders will carry sixteen times as much under one set of conditions, as they will under another set. This is a particularly instructive set of examples, because it will show you that the dimensions and weight of ironwork are not altogether dependent upon stresses, but that there is in any structure plenty of scope for good designing. You will find the girder with fixed ends commonly occurring as part of a continuous girder: that is, one continued over several supports, as in the railway bridges over the Thames.

The typical form of a girder, taking a cross section, is shown in Fig. 48, consisting, as you see, of a top and bottom flange kept apart by a web, and prevented from twisting by

means of angle irons in the case of wrought-iron girders, and by casting in one piece in the case of cast-iron girders. The flanges and the web are the main parts; angle irons, stiffeners, cover plates, rivets, &c., being mere details of construction.

We have considered the loading of different girders from what we may call a common-sense point of view, which we shall find very useful presently, but we must look a little closer into the effect of these loads; the simplest case will be that of our first example, the cantilever, loaded at the end, Fig. 49.

It is clear that the load will tend to cause the girder to bend down, as in Fig. 50, and it is also clear that this bending strain is made up of a stretching or tension in the top flange, and a crushing or compression in the bottom flange. The web is not considered to render any assistance in resisting these strains, its sole duty being to keep the flanges apart, but there is a strain in it due to the direct action of the load which will claim our consideration. We may look upon the bending strain as simply a question of leverage, and there are three ways of considering it, all coming to one result, Figs. 51, 52, and 53.

The load multiplied by the length of the cantilever = the moment of the power in each case. Then for the moment of the weight we have in the first case the resistance in the top flange $\times$ ½ the depth, + the resistance in the bottom flange $\times$ ½ the depth. In the second case, the moment of the weight will be the resistance in top flange $\times$ whole depth, and in the third case resistance in bottom flange $\times$ whole depth. Putting letters for words, we have these equations:

$$\text{I. } W \times l = (t \times \tfrac{1}{2}d) + (c \times \tfrac{1}{2}d)$$
$$\text{II. } W \times l = t \times d$$
$$\text{III. } W \times l = c \times d;$$

or putting the same statements as formulæ:

$$\text{I.} \quad t + c = \frac{W \times l}{\frac{1}{2} d}$$

$$\text{II.} \quad t = \frac{W \times l}{d}$$

$$\text{III.} \quad c = \frac{W \times l}{d};$$

so that, whichever way we consider it, the strain is equal in each flange. To take an example, say—load 4 tons, length 8 feet, depth 2 feet, strain in either flange $= \frac{4 \times 8}{2} = 16$ tons. This is of course the strain next to the wall, where the full length of the cantilever comes into action. If we want the strain at any immediate point x, Fig. 54, we take the horizontal distance W x as leverage of the power, and by working out a few points we shall find that the strain along the girder is exactly proportional to the distance from the load, and that immediately under the load, as there is no leverage, so there would be no strain.

This can be shown geometrically in a beautifully simple manner. If we set up A a to any given scale, making it equal to the maximum strain as found by the calculation, and then join a with the point under W, the vertical height or ordinate from the base, at any point x, will give the amount of strain in the flanges of the girder at that point, being tension in the top flange, and compression in the bottom flange. The whole thing may be done geometrically if required, thus, Fig. 55: put the girder down to scale, join the top of the girder b at one extremity with the bottom c at the other extremity, produce the line of underside of girder A c indefinitely, set up A d = W, draw $d e$ parallel to $b c$, from point A with radius A e describe an arc, and continue A d to

meet it in *f*, then A *f* will equal the result found by the previous calculation, viz. the maximum strain on the girder. The advantage of the geometrical method is that it can be used just as readily if the question be full of fractions, but the result is of course only approximate, depending upon the neatness in working. If you are careful to use a good scale, and a hard pencil with a fine point, the result will be near enough for all practical purposes.

I mentioned that there was also a strain due to the direct action of the load; this is a shearing strain, and is assumed to be borne entirely by the web. It is a difficult mathematical investigation to prove what part the flanges and web respectively take in resisting the various strains, but it is found to be practically correct to assume that the tension and compression are taken by the flanges, and the shearing by the web. The tendency of a shearing strain is to cause one section of the girder to slide on another, as if cut or sheared, as shown in Fig. 56.

In the case of a cantilever loaded at the end, the shearing strain is uniform throughout, except for the slight alteration made by the weight of the girder itself, and is equal to the load. If the load be 20 tons, the shearing strain will be 20 tons, or allowing 4 tons per square inch, the sectional area of the web must be 5 square inches, and uniform throughout its length. The shearing strain would be indicated geometrically, as in Fig. 57. Drop line A *b* = W, draw W *c* vertically, and *b c* horizontally, then ordinates from base line of girder to *b c* give the strain at any point. All the ordinates being equal, the strain is seen to be uniform.

QUESTIONS FOR HOME-WORK.

1. A rafter 11 feet long, with one end 5 feet 8 inches higher than the other, has a distributed load of $2\frac{3}{4}$ tons; what will be the horizontal thrust at each end, and what the load upon the wall at the foot?—Ans. Thrust 2·28 tons, load 2·75 tons

2. A trussed beam 24 feet span has a concentrated load upon it of 10 tons, 8 feet from one end, the strut is directly under the load, and 12 feet long; what will be the amount and nature of the strain in each portion?—Ans. See Fig. 58.

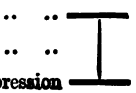
3. A tall man and a short man have a load slung on a pole midway between them; which will bear the greater proportion of the load, and why?—Ans. The bearings will be in line with pole (see Fig. 59), the load on each man will be $\frac{W B}{2 H} = \frac{1}{2} a$. There will also be a sliding tendency to be stopped by friction, amounting to $\frac{W P}{2 H} = \frac{1}{2} b$ on each man. But there will be a tendency for the load to work downwards towards the short man, who will then have to bear the greater proportion.

4. If a cantilever carry a load of $7\frac{3}{4}$ tons safely at its extremity, how much would it carry evenly distributed?—Ans. $15\frac{1}{2}$ tons.

5. If a girder supported at both ends just break with a distributed load of 27 tons, what load placed in the middle would cause its fracture?—Ans. $13\frac{1}{2}$ tons.

6. Sketch a typical form of girder in section, and name the strains in each part when fixed as a cantilever and loaded in the middle.

Ans. Top flange, tension .. ..
Web, shearing .. .. ..
Bottom flange, compression



LECTURE IV.

Effect of distributed load—Strain varies as the ordinates to a parabola—Setting out parabola—Method when particular points only are required—General calculation of strains in a girder divided into three stages: pressure on supports, strain in flanges, strain in web—Girder with concentrated load in any position—Maximum strain immediately under load—Variation of strain between extremities—Investigation by diagrams and formulæ—Also by leverage—Combination of diagrams from two or more loads—Special diagrams for rapid use—Girder with distributed load, method of finding strains—Proportioning material to resist the strains—Examples.

If a cantilever be loaded with two or more weights, we can find the collective result by taking each result separately, in the manner shown in the last lecture, and then adding them together. The extreme case will be when the cantilever is loaded uniformly throughout its length. We shall find the *maximum* strain only one-half of what it is with an equal load concentrated at the outer end; the effect is the same as if the whole of the load were collected at its centre of gravity, which would be half way along the cantilever, and have therefore only half the leverage, as in Fig. 60. The intermediate effects will, however, not be similar. If we calculate the result of each of these small weights at its respective leverage, we shall find that we do not obtain a uniform difference of strain along the girder as before. Putting down the heights found for the strain at the various points, we shall find that they form a curve instead of a straight line. This curve will be one-half of what is called a parabola, with the vertex at end of cantilever, and, as it is quite indispensable to be able to construct one of the right shape and any given size, I will tell you how to do

it. Let A, B, Fig. 61, be the length, and A C the height; divide A B into any number of equal parts, and A C into the same number. Set up B D equal and parallel to A C, join C D, and from each point on A B draw a vertical line parallel with A C. Then join B with each of the points on A C, and through the intersection of the lines from similar points on A C, A B, draw the curve C B. Then, ordinates or vertical measurements from any point on A B to the parabolic curve will give the strain at that point.

But suppose we only want to know the strain at one or two particular points, we need not draw the whole curve, thus: required the strain at A, *x*, and *y*, Fig. 62. We will divide this into two diagrams to show the separate stages more clearly, although in practice you would work right through on the one figure. First, for the strain at A, this will be equal to the height of the parabola and may be found geometrically. Take A B as the base line, Fig. 63, and *g* as the point under the centre of gravity of the load, then A *g* will be the leverage of the load. Let A *c* = depth of girder, join *c g*, set up A *d* = load to any given scale, and from *d* draw *d e* parallel to *c g*, then from point A with radius A *e* describe an arc cutting A *d* produced in point *f*. Then A *f* will be the strain in the flanges at point A. Now for the strains at *x* and *y*, see Fig. 64: set up A *f* from the last figure, and B *h* equal and parallel to it, join *f h*, and draw vertical lines from *x* and *y* to meet *f h* in points *m* and *n*. Join A *h* and draw *m o*, *n p*, parallel to A *h*; join *o* B, *p* B, then where *o* B cuts *m x* call the point *q*, and where *p* B cuts *n y* call the point *r*. Then *x q* will be the measure of the strain in the flanges at *x*, and *y r* the strain at *y*.

With a cantilever loaded in this manner, the shearing strain, instead of being uniformly equal, is uniformly reduced, being equal to the total weight at the support end, and tapering off to nothing at the outer end, as in Fig. 65, the vertical height at any point being the measure of the shearing strain at that point. You will observe that shearing strains are usually

shown below the girder, while flange strains are shown above it, using the bottom of the girder as a base line.

Our investigation of the strains in a cantilever will help us to understand more readily those in an ordinary girder supported at each end. First, with a concentrated load, Fig. 66; we may divide the calculations into three stages, viz.: the pressure on the supports, the strain in the flanges, and the strain in the web. We have seen already how to find the pressure on the supports, but I will show you a slight modification of the same principle, which will also be useful as leading up to the discovery of the strains in the flanges.

Let A B, Fig. 67, be the girder with span l, and W the position of the load, dividing the span into the portions x and y; take a large scale, as there are several lines to put on. Set up B c = the load on the given scale, join A c, then the vertical height between the bottom of the girder under the the load, and this line, viz. $e\,d$, will be the proportion of the load borne by support at B. Draw $c\,f$ parallel to girder, and produce $e\,d$ to f, then $d\,f$ will be the load on support A, the whole load $e\,f$ being divided between the supports A and B in the proportions $e\,d$, $d\,f$.

Now $e\,d$ being the load on B, we may look upon the resistance, which is of course equal to the pressure, as an active reaction or power, with the leverage y, and we get the following proportion:—As depth of girder : leverage :: reaction at support : strain in flange. I will give you a little sketch, as soon as we have done with the present one, which will put this proportion in a very clear light.

To resume our construction, let $e\,g$ be the depth of the girder, then join g B and from d draw $d\,h$ parallel to g B; then $e\,h$ will equal the strain because

$$e\,g \;:\; e\,\mathrm{B} \;::\; e\,d \;:\; e\,h.$$

From e as a centre, with radius $e\,h$ describe the quadrant $h\,i$, join i A, i B; then the strain in the flange, at any point, will be obtained by ordinates from A B to A i B.

If we had taken support A as our starting point, we should have worked in a similar manner, and have arrived at precisely the same result; so that it does not matter at all which side we take for the flange strains, but it does matter as regards the shearing strain, as I shall now proceed to show you. In the case of a concentrated load the shearing strain is uniform throughout, when the load is central; but when the load is out of the centre, the shearing strain is measured on each side by the proportion of the weight which is carried by the support. To indicate this graphically we must make some additions to our sketch. Drop A j = W, join j B intersecting i e produced in k, draw k m vertical and j m horizontal, then e k will be the shearing strain on side A, and k m the shearing strain on side B; but we must show it on the sketch a little more clearly. Draw m n parallel to j B, draw horizontal lines n o and k p, then the shearing strain at any point will be given by ordinates to the outline A p k o n B.

Now for the sketch that is to explain in a very simple way the strength of a girder by leverage (Fig. 68). Here we have two levers joined at right angles to each other at the fulcrum, and shown by thick lines; viz., the length from load to support, and the depth. Then we have the load which gives us the *position* of the fulcrum, the reaction at B which is influenced by the amount and position of the load, and S the resistance in either flange under the load, say the compressive stress in the top flange. From these particulars we obtain the following proportions:

$$l : x :: W : B$$
$$d : y :: B : S.$$

Putting the latter into an equation, we have $S = \frac{B \times y}{d}$

but B is made up of $\frac{W \times x}{l}$ as shown by the former proportion, and as we found in considering leverages; we may

therefore rub out the B, and replace it by $\frac{W \times x}{l}$ thus:

$$S = \frac{\frac{W \times x}{l} \times y}{d},$$

and the same thing in a simpler form will be

$$S = \frac{W \times x \times y}{l \times d},$$

but in a formula of this kind it is unnecessary to put the sign of multiplication; if the letters are simply written against each other, thus,

$$S = \frac{W\,x\,y}{l\,d},$$

it is understood that those above the line are multiplied together, and those below the line are multiplied together, the line indicating that the upper group is divided by the lower group.

Algebraically, the shearing strain on either side of the load is found in the same way as the pressure on the supports, viz.:

$$\text{Side B} = \frac{W\,x}{l}, \text{ side A} = \frac{W\,y}{l}.$$

If there are two or more concentrated loads, the strains due to each must be worked out separately and added together. If they are worked out geometrically, a separate diagram is made, upon the same foundation, for each load, and the two diagrams are combined to form a final diagram. In adopting this method care must be taken that any portion of the second series of strains overlapping the first is added on to the outside, as in Fig. 69. Take A B as a girder supported at the ends, *c d* as the position of two loads, and A *e* B, A *f* B, the strains in the flanges produced by the respective loads. The two diagrams overlap at the shaded

part A *g h i* B. Add *c g* above *e* = *e j*, *d i* above *f* = *f k*, then join A *j k* B which will represent the combined diagram from the two loads.

In finding the strain from a *distributed load* by leverage, you must bear in mind that the reaction to be taken at the support is only half the load on the support, as previously explained, or one-fourth of the total load, the other one-fourth upon the support resting there direct, without affecting the maximum strain on the girder (see Fig. 70). If this point be remembered, the leverage mode is by far the better way to work out an examination question, because you can reason it all through without being dependent upon your recollection of formulæ.

The form of diagram which I have selected in each case has been that in which you can trace the reason for the different lines, in order to assist you to think out the combinations in other examples. There are some simpler forms very readily applied, and depending upon the principles you have already learnt; but not so self-evident. Here is one (Fig. 71), giving all the strains in a girder carrying a single concentrated load. From A drop a vertical line A *c* = the weight, on any given scale; join B *c*, drop a vertical line from W cutting B *c* in *d*, from *d* draw *d e f* horizontally, cutting A *c* in *e*, join W A and produce the line to meet *d e f* in point *f*. As a check upon the working, *f c* ought to be found parallel with W B. Then A *e* will be the load on A, *e c* the load on B, A *e* will also be the shearing strain between A and W, *e c* that between B and W, and *e f* will be the maximum strain in the flanges under the load, giving tension in bottom flange and compression in top.

If there were a second load, the strains from it might be worked out at the other end of the girder, and the two sets combined on the top.

There is an alternative method of working this diagram which I will give you with the same lettering (Fig. 72). I

have departed from the usual method of taking a central load for consideration first, and then assuming it out of the centre, because it is apt to mislead and cause you to think that different methods must be adopted according to the position of the load, whereas one method answers all purposes.

In all these diagrams you will observe that, although the girders are supposed to be drawn to scale, I terminate them at the edges of the supports, because, theoretically, that includes the whole of the portion under strain.

There is sometimes shown an extension of the last diagram, by which the strain is found at any point, as well as the maximum strain; see Fig. 73. On a girder A B C D, with load at W, set up A e = load on A, and B f = load on B, produce A W to meet a horizontal line from e in point g, and B W to meet line from f in point h. Then, to find the strain at any point in the top flange between C and W, draw line from A through the point to meet line $e g$, and the distance from e along the line $e g$ will be the strain. Also for the strain between W and D, draw line from B through the point required to meet $f h$, and the distance from f will be the measure of the strain. The maximum strain will be either $e g$ or $f h$, which will be equal to each other. The strains in the bottom flange will of course be equal to those in the top flange, at the same horizontal distances from the abutments. This is a neat diagram, but on the whole is not so useful for practice as one giving the maximum strain, which is then placed over the load, and lines drawn to the supports, as in the large one (Fig. 67), given this evening. The reason will be seen when we look at the mode practised by draughtsmen for finding the proper lengths of the plates in a girder.

Suppose the girder to have a concentrated load, and the maximum strain requires that four $\frac{5}{8}$-inch plates shall make up the thickness just under the load; we set off the four

⅝-inch plates full size at the point of maximum strain in the flanges A B, and join the highest point with the extremities. Then we draw the plates so far that they overlap the "strain-line" just far enough to allow of the rivets securing the ends, as in Fig. 74.

The due proportion of the amount of material in the different parts of a girder belongs to "practical designing," such as you will find exemplified in a series of handbooks to be published shortly.* At present we must confine ourselves to finding the strains, and there are a few other cases of transverse strain which we must consider before we return to framed structures. We shall complete this portion of our subject in the next lecture.

QUESTIONS FOR HOME-WORK.

1. A cantilever of wrought iron is loaded with a weight of 3 tons at the end, and 4 tons spread uniformly along it; the length is 7 feet and the depth 1 foot; show how all the strains are obtained, and state their amount at a point 3 feet from the support.—Ans. (Diagram not drawn):

From end load, tension and compression	12·00
„ distrib. „ „ „ „	4·57
Total	16·57
From end load, shearing	3·00
„ distrib. „ „	2·28
Total	5·28

2. Work out geometrically all the strains in a girder 20 feet span, 1 foot 8 inches deep, with a concentrated load of 5 tons 5 feet from one

* 'Designing Wrought and Cast-iron Structures,' by Henry Adams. Part I., Wrought and Cast-iron Girders, now ready.

end, and prove the result algebraically, excluding the weight of the girder itself?—Ans. (Diagram not drawn):

Flanges, under load	.. ..	=	11·25 tons.
Load on A	.. ..	=	3·75 „
Shearing, W A	.. ..	=	3·75 „
Load on B	.. ..	=	1·25 „
Shearing, W B	.. ..	=	1·25 „

3. A girder, 20 feet span, 20 inches deep, has a load of 3 tons at 5 feet from one end, and 2 tons at 5 feet from the other end; what is the nature and amount of the strain in the top flange at the centre of the span, excluding weight of girder?—Ans. 7·5 tons, compression.

4. In the last case, what additional strain would be caused if the weight of the girder (30 cwt.) were taken into account?—Ans. 2·25 tons.

LECTURE V.

Girder with distributed load, other forms of diagram—Construction of ordinary formulæ—Girders with intermediate supports—Continuous girders—Proportion of spans—Action of load—Points of contrary flexure—Diagram of strains—Formulæ—Humber's Handy Book, recommended for general reference—Moving loads—Moving loads on cast-iron girders—Factor of safety—Formula for cast-iron bridge girders—Strength of beams, ⌊ and ⊤ irons—Transverse strains on rafters—Struts, stanchions, and columns—Joints and fastenings—Rivets, pins, and bolts—Single or double shear—Examples.

This evening we have to finish the cases of transverse strain. We will commence with a girder under a uniformly distributed load, an exceedingly common case, and I will show you how the formula in "Molesworth" and elsewhere is made up. For the load on each support (see Fig. 75) we take one-half the total load: this you have seen before. For the strain in the flanges, it is evident that the greatest strain would be in the centre at *e*. In finding the amount of the strain, we may say that half the load on *e* D is resting direct upon B, and the other half, or one-fourth the total load, is producing the strain, with the leverage *e* D against the depth B D, as in Fig. 70, then

$$\text{B D} : e\,\text{D} :: \tfrac{1}{4}\,\text{W} : \text{strain},$$

but $e\,\text{D} = \frac{1}{2}$ length, say $\frac{1}{2}\,l$; and D B = depth, say d; therefore,

$$d : \tfrac{1}{2}\,l :: \tfrac{1}{4}\,\text{W} : \text{strain},$$

or

$$\text{S} = \frac{\frac{1}{4}\,\text{W} \times \frac{1}{2}\,l}{d},$$

or, multiplying by $\frac{1}{4}$ and dividing by 4, being the same thing, we may get rid of fractions, thus:

$$S = \frac{W \times \frac{1}{2} l}{4 d},$$

and again, dividing by 2 instead of multiplying by $\frac{1}{2}$, we get

$$S = \frac{W l}{8 d},$$

which is the ordinary formula for the strain in the centre under a distributed load.

To find the strain at any other point m, Fig. 76, the formula will be $S_m = \frac{W x y}{2 l d}$, and if the load be given at per foot run $= w$, we take the whole load as $w l$, so that our formulæ become

$$S = \frac{w l^2}{8 d}, \quad \text{and } S_m = \frac{w x y}{2 d}.$$

To obtain the strains geometrically, draw your girder to scale, say A B, Fig. 77, with depth $c d$, set up a centre line at c, and mark off $c w =$ *one-fourth* the total load, join d B, and parallel to it draw $w e$. From c as a centre describe the quadrant $e f$, then $c f$ will be the flange strain in the centre. Next set up A g, and draw $f g$ horizontally to meet it in g, mark off A c into any number of equal parts, and A g into the same number, draw vertical lines from the points on A c, and cut them by lines drawn from f to the divisions on A g; these points of intersection will give half a parabola with its vertex at f, and the height to the curve at any point will equal the strain. We need not draw the other half of the parabola, as the strains will be exactly similar on both sides of the centre line. For the shearing strain join B w, and produce it to cut A g in h, join $h c$, then vertical

measurements from A c to $h\,c$ will give the shearing strain at any point. You will find that it is equal at the supports to half the load, and disappears at the centre.

The rapid diagram shown in the last lecture for a concentrated load will apply, with a slight modification, to the case of a distributed load.

Let A B, Fig. 78, be the girder, with depth $c\,d$. Drop A $e = \frac{1}{2}$ W (W = total load), join e B, drop $c\,d$ to f, join c A and produce the line, draw $f\,g$ horizontally, and produce to cut line through c A in point h; join $d\,e$. Then $g\,h$ will be the maximum strain in centre of flanges, A e the load on each support, and ordinates from A d to $e\,d$ will give the shearing strain in the web.

There is an arrangement adopted in some bridges by which lighter girders can be used, and that is by putting in intermediate supports, or we may say the girder is continuous over so-many spans, and therefore generally called a continuous girder. Suppose we have one continued over three spans, as in Fig. 79, the outer ones being preferably about $\frac{2}{3}$ths the length of the middle span. The tendency of the girder under a distributed load will be to bend, as in Fig. 80, the thick lines showing the parts in compression, the thin lines those in tension, and the effect will be the same as if there were three girders fixed firmly at their ends over the intermediate piers.

The points in the flanges where the strain changes from compression to tension, and *vice versâ*, are called the points of contrary flexure, or in plain English, the points where the bending reverses. A graphic diagram of the strains obtained from formulæ will show, easily and clearly, both their nature and amount. Taking w as the load per unit of length, and the girder as of uniform strength, set up E F in the centre of span a, Fig. 81, $= \frac{w\,a^2}{8\,d}$, and construct a parabola

A F B. Then at B erect B G equal to $\frac{w\,a^2}{6\,d}$. Join A G intersecting A F B in H. Then H will be vertically over the point of contrary flexure, A F H will give the compressive strain in top flange and H G B tensile strain in top flange, measuring vertically on the shaded part of the diagram.

At centre of span B C set up I J = $\frac{w\,b^2}{8\,d}$, and construct parabola B J C, set up B G and C K each = $\frac{3\,w\,b^2}{3\,2\,d}$; but if this value be less than that formerly found for B G, then use the former value, if greater use the present and alter line A G accordingly. Then join G K, intersecting B J C in L M. B G L will give tensile strain in top flange, L J M compressive strain in top flange, and the remainder of the girder will be similarly strained to the parts already taken. The strains in bottom flange will be equal throughout to those in top flange, but of opposite character.

There are of course very many varied conditions of load, construction, and support, in the girders that you meet with in practice; it would take too long to investigate the whole of them here, but I think I have told you enough about this portion of the subject to enable you to work out for yourselves other cases, or at any rate to understand the working out from such a book as Humber's "Handy book of Strains," a little volume which I look upon as indispensable to all having to do with girder work. There you will find much useful information, but it is so condensed that you would make nothing of it unless you had some previous general knowledge, such as I have now given you.

From whatever source you obtain your mode of working, be careful to see that you have the units of measurement correct, because sometimes *w* stands for the whole load, and

at other times for the load per foot run; in some formulæ s stands for span in feet and in others for span in inches, and so on. In all the cases we have taken, I have described the value of w, and for span we have assumed the same unit as for depth, both being either in feet or in inches.

As regards the nature of the load, we have assumed dead, fixed, or slowly applied loads, but there are cases in which live, moving, or suddenly applied loads must be estimated for, and with these you will obtain different results. The actual strain caused by a moving load is very difficult to determine, and depends partly upon the amount of deflection caused in the structure. This again is subject to the quality of the workmanship, the nature of the material, and the mode of connecting the parts, in such a way that it can only be approximately determined beforehand. From various experiments and theoretical deductions certain allowances are made, which principally affect cast iron, as it is considered to be to a great extent a treacherous material, and therefore a greater margin for safety must be provided. The only allowance of the kind that I need call your attention to now, is in connection with cast-iron girders for bridges, my formula for which is as follows, assuming the ultimate tensile stress of cast iron to be $7\frac{1}{2}$ tons per square inch:

$$\text{s. a. bott. flange} = \frac{\text{span in ft.} \times \left\{ \begin{array}{l} 5 \text{ times dist. dead load tons} \\ +\,8 \text{ times dist. live load tons} \end{array} \right.}{5 \text{ times depth in inches.}}$$

From this you will see that the moving load is assumed to distress the material more than an equal dead load, in the proportion of 8 to 5. The Board of Trade allowance is, I think, rather less than this, but I consider the above a good safe formula and worth noting.

It may be useful to give you a very handy little formula for the mental calculation of wrought and cast-iron girders per-

fectly accurate under certain conditions, but approximately correct under any other conditions.

Wrought iron dist. load, any span, any load, depth = $\frac{1}{12}$ span
s. a. top flange = ·3 W.

Cast iron dist. load, any span, any load, depth = $\frac{1}{12}$ span
s. a. bottom flange = W.

W being total load in tons, and the area in square inches.

In a solid girder, such as a wooden beam or the test bar used for judging the quality of cast iron, the transverse strains are not found in the same way as those in a flanged girder; but as these calculations are not much required by the engineer, and we have previously investigated them in the course of lectures on "Timber," we need not go into it again now.

Angle and tee irons are of course used very largely in positions in which they are subject to transverse strain; the proportioning of the amount of material depends upon a calculation in which the centre of gravity of the section and the neutral axis have to be found. This belongs to designing, but there is something more to say under the head of Strains bearing upon this part of the subject.

When you have an inclined rafter of angle or tee iron, say with a uniformly distributed load, there are two ways of obtaining the value of the cross strain.

Let A B (Fig. 82) be the rafter, and C B the height of B above A, then the calculation may be made the same as for a girder under a distributed load, taking A C as the length or span instead of A B, and bearing in mind that the depth *d* in the formula will depend upon the form of the cross section. Or we may take it another way; and say that $\frac{1}{4}$ the load is carried direct upon each abutment, and $\frac{1}{4}$ transmitted to each abutment *through* the rafter, these $\frac{2}{4}$ acting in the centre and producing a cross strain, the *amount*

of which will vary according to the angle of the rafter, and the *effect* according to the form of the cross section. Rafters are always made of uniform section, and we therefore want only the maximum strain, which will be in the centre. Take $\frac{2}{4}$ths or $\frac{1}{2}$ the load as acting vertically on the centre with the span A C; or by parallelogram of forces, let $d\,e = \frac{1}{2}$ W (Fig. 83), draw $e\,f$ parallel to B A, and $d\,f$ parallel to the direction in which the effect is required, viz., perpendicular to B A, then $f\,d$ will equal the cross strain in the centre upon the length A B and perpendicular to it. This will be a strain for which additional material must be provided beyond that required for resisting the compression transmitted by the rafter due to the arrangement of the trussing.

When a rafter or strut is inclined, although it may have no external load except one acting in the same direction as itself and producing compression, it is still subject to a cross strain from its own weight taken as a distributed load. The ties of a structure are also subject to the same conditions, but being generally lighter, and tensile stress resisting rather than assisting the bending, the effect is not so important.

Vertical struts, as stanchions and columns, are subject to a bending action owing to the practical conditions of manufacture, erection, and loading never being theoretically perfect. So far as the calculation of strains is concerned, all we can obtain is, the dead load producing compression; but in designing columns we have to make allowance for this bending tendency, and, unless tables are referred to, it can only be done by logarithms, which is a hard name for an easy subject.

Joints and fastenings must always be at least equally strong with the parts they connect; as a general rule they are formed of rivets, pins, or bolts, the strain upon them being a shearing strain, tending to cut them through either *at one point* or *at two points*. This question of single or

double shear must be practically noted, because, often you may find that a certain set of rivets &c. can only fail by being sheared through two places at the same time, and then you may take half the shearing force to obtain the requisite sectional area.

We have now taken all the simple cases, forming, as it were, the foundation upon which we can consider the complex cases. The Warren girder forms a very suitable example upon which to try our skill, and we shall proceed with this in the next lecture.

QUESTIONS FOR HOME-WORK.

1. In a girder 20 feet span, 1 foot 8 inches deep, with a uniformly distributed load of 5 tons, including weight of girder, what will be the nature and amount of the various strains at a point 5 feet from the right-hand support?—Ans:

Compression, top flange	5·625 tons.
Tension, bottom flange	5·625 „
Shearing web	1·25 „

2. A plate girder bridge is continuous over three spans of 15, 20, and 15 feet respectively, its depth is 2 feet, and the load distributed $1\frac{1}{2}$ tons per foot run on each girder; show by diagram the strains throughout. Scales $\frac{1}{4}$ inch = 1 foot and 1 ton.—Ans. (See Fig. 84.) E F = $21\frac{3}{4}$, B G = $28\frac{1}{2}$, I J = $37\frac{1}{2}$.

3. A rafter carries a distributed load of 2 tons, it is inclined at an angle of 30°, what will be the effect in transverse strain on the rafter? —Ans. ·87 tons in centre.

4. What size should the bottom flange of a cast-iron bridge girder be in the centre, when the span is 20 feet, the depth 2 feet, the dead load 5 cwt. per foot run, and the moving load 30 cwt. per foot run?—Ans. 44·17 square inches: say, 18 inches × $2\frac{1}{2}$ inches = 45 square inches.

LECTURE VI.

Open web girders—Warren, lattice, and trellis girders—Angle of inclination of bars—Proportion of depth to length—Warren girder under central concentrated load—Application of parallelogram of forces—All bars equally strained—Strain in flanges cumulative towards the centre of span—Value of strain at each part in terms of x—Vertical ends to girders, how affected by position of last bar—Warren girder under distributed load—Apportioning the load on each span—Action of load from point of application to each support—Bars not equally strained—Strains worked out by parallelogram of forces, commencing at support—Strains on cranes—Ordinary mode of working incorrect—Application of load is diagonally through sheave pin—Angle of jib affects strains—Examples.

We will now apply our knowledge of the transmission of forces to ascertain the strains brought upon the several parts of a girder formed of open triangles, called a Warren girder, as in Fig. 85. When the bars cross each other, as in Fig. 86, it is called a lattice girder, and when several bars cross, as in Fig. 87, it is called a trellis girder.

In a Warren girder the lattice bars are placed at an angle of 60°, making the triangles equal sided, and the bars therefore equal in length to the width of a bay. The *depth* of the girder will always be a fixed proportion depending upon the number of bays in the span, and being ·866 or nearly $\frac{9}{10}$ths the width of a bay, this being the proportion the perpendicular height of an equilateral triangle bears to its base.

You will find it handy to note down this sketch of an equilateral triangle (Fig. 88), and the following equations:

$a\,b = 1$, then $c\,d = \sqrt{\cdot 75} = \cdot 866$, and $a\,d = \cdot 5$.
$a\,b = 2$, „ $c\,d = \sqrt{3} = 1 \cdot 732$; „ $a\,d = 1 \cdot$
$c\,d = 1$, „ $a\,c = 1 \cdot 155$, and $a\,d = \cdot 577$.
$c\,d = \cdot 5$, „ $a\,c = \cdot 577$, „ $a\,d = \cdot 288$.

$\sqrt{2} = 1 \cdot 414$ $\sqrt{3} = 1 \cdot 732$.

Also the sketch of a right-angled triangle with two equal acute angles, the longest side or hypothenuse forming an angle of 45° with the other two sides (Fig. 89).

$$bc = ac.$$

$bc = 1$, then $ab = \sqrt{2} = 1{\cdot}414.$

$ab = 1$, „ $bc = \sqrt{{\cdot}5} = {\cdot}707.$

These figures will enable you to sketch down the strains in lattice girders, by the parallelogram of forces, and follow the value of the lines through, without measuring. They are particularly useful if you have no knowledge of trigonometry.

To return to our Warren girder: if the depth appear too great, or too small, the number of bays must be modified accordingly. We will assume only 3 bays in order to reduce our work, but generally you would not have less than 5, and might have as many as 13.

We will consider this girder under four different conditions: with the load concentrated and distributed, and with the number of bays even and uneven.

First, with a concentrated load in the centre on the top flange, and an even number of bays, as in Fig. 90.

We have this load supported primarily by the two struts meeting underneath it, and as we know that half the load passes through each of them towards the support, these will be in compression, and the amount will be found by parallelogram of forces, as in Fig. 91, the vertical dotted line being equal to W; taking one of these struts, we find at the bottom it produces (Fig. 92) tensile strain in the next inclined member, showing it to be a tie, and also in the bottom flange. The other strut produces similar strains on the other side. Then the tie, Fig. 93, brings a compressive strain on the next bar and on the top flange. This bar being the last, the strain transmitted by it is resolved into downward thrust, or dead weight on the support and tension in the bottom flange, as in Fig. 94. The ends of the top

flange, and the vertical ends of the girder do not receive any strain; and the proof is that we have now traced the action of the load right through to the supports without passing through these portions.

Upon putting this down to scale, you will find that with a single central load all the bars are equally strained, and with only three bays the top flange is uniformly strained throughout the two central bars, but the bottom flange has the strain from the *end* struts transmitted through it from end to end, and in the central portion it has the additional strain from the middle struts. Whatever the number of bays, the rule with a central load will be that the lattice bars are all equally strained, but the flanges will be strained in an increasing ratio towards the centre of the span, depending upon the number of bays upon each side producing a cumulative strain.

Now, by reason of our knowing the proportions of an equilateral triangle, we can find the strains very easily by calculation. Suppose our girder to be 15 feet span, the width of each bay will be $\frac{15}{3} = 5$ feet, and the depth of the girder $5 \times \cdot 866 = 4 \cdot 33$ feet, or say, 4 feet 4 inches. Let the load be twelve tons, then the strains will be found thus:

s = span in feet.
n = number of bays.
b = width of bay $= \frac{s}{n}$.
d = depth of girder $= \cdot 866\frac{s}{n}$.
l = length of bar in feet $= \frac{s}{n}$.
W = concentrated load in tons.
x = strain on centre bars;

then,

$$d : l :: \tfrac{1}{2}W : x,$$

$$\text{or } x = \frac{\frac{1}{2}Wl}{d}, \text{ and this is } = \frac{W}{1{\cdot}732}, \text{ or } {\cdot}577\,W.$$

In this case, x will $= 6{\cdot}95$ tons, and the strains will be as marked in Fig. 95, the dotted parts having no strain in them.

It might be supposed that the strains in the flanges could be found from the formulæ we have previously taken, or by leverage, and this would be right for the bottom flange of this girder, but not for the top. The strain in the top flange is not due to the direct action of the load, but to the compression resulting from the two bars shown in tension, and the amount would be the same as if we took one bay for leverage, instead of $1\frac{1}{2}$ as we should at the bottom. It will also be noticed that between the points of attachment the various portions of the girder are considered to be under uniform strain, so that a curve of strain say for the bottom flange would be something like a shearing diagram, Fig. 96.

Now we will take the load in the centre again, but use a girder having four bays, the additional bay being placed half at each end of our last girder, as in Fig. 97, increasing the length to 20 feet, the other dimensions remaining the ame .

If I thicken the lines in compression, and mark on each part the value of the strains in terms of x, I think you will understand it without going through the working again. (See Fig. 98.)

The dotted portion at each extremity has theoretically no strain, but is of course required to hold the vertical end in its place, and to give sufficient bearing surface for the end of the girder on the supports. It also shows you that a girder thus constructed may be supported at the ends of the top flange, if properly designed, the supports taking the place of the vertical ends.

We will now go back to our first girder of three bays, and put a distributed load of the same amount upon it. From a mere inspection of the bracing we can predict what the nature of the strains will be, and I may therefore just as well draw the girder at once in thick and thin lines, Fig. 99.

If the total weight be 12 tons distributed, and the girder 15 feet long, it will be $\frac{12}{15} = \cdot 8$ tons per foot run. We must see how much of this will come on each apex or supporting point, Fig. 100; from *a* to *b* we have 2·5 feet, which $\times \cdot 8 = 2$ tons; from *b* to *c* 5 feet $\times \cdot 8 = 4$ tons, *c* to *d* again 4 tons, and *d* to *e* the same as the other end = 2 tons. Now, of the first 2 tons half is borne by the vertical bar at the end and the other half by the first pair of inclined bars. Then, with the 4 tons, we have half on each apex at the sides of that bay, and so on. Adding these half-loads together, we get 1, 3, 4, 3, 1.

In order to get the strains correctly with a distributed load, or a load or loads out of the centre, it is necessary to work from the abutments towards the centre, and we must therefore find the pressure on the abutments next. To do this, we find the centre of gravity of the load, and obtain the result by leverage as previously explained. In this case, as the load is symmetrical, the pressure on each abutment will be half the total load, or 6 tons. But there is 1 ton acting exactly opposite to it in *e* B and *a* A, so that the amount acting through the girder trussing will be $6 - 1 = 5$ tons. Tension and compression may be conveniently indicated by the signs − and +. By parallelogram of forces, Fig. 101, we resolve the 5 tons at B into 2·9 tons in *g* B, and 5·8 tons in *d* B. Transferring the strain in *d* B to its upper end, we then have the load on *d*, and the strain in *d* B, both acting at point *d*, and we want to find the effect in *g d* and *c d*. Before this can be done, we must compound the two forces + 5·8 and 3·0 into one, as shown at *h d*, then resolve its effect into the two parts *c d* and *g d* = 4·0

and 2·3 respectively. Transferring the strain in dg to its lower end, we have it acting upon fg and cg, producing strains in each, equal to 2·3. Now we add the strain in Bg to that in fg, and we obtain the accumulated strain in fg = 5·2. The other half of the girder will be exactly similar.

I worked the strains in the first example this evening from the load towards the abutment, because it appears to be more direct, and when we omit the weight of girder there is no difficulty; but you must take it as a general rule that in any case the strains should be worked from one abutment towards the other. In practice, of course, you never get a concentrated load alone: you have always the weight of the girder itself as a distributed load in addition to the other. The weight of girder is allowed by taking it as being divided over the various points of support, viz. the apex of each bay, precisely in the same way as you would consider it if it were an *external* distributed load.

I have now shown you sufficient of the application of the parallelogram of forces to lattice girders to enable you, with time and patience, to work out any example that may arise; the consideration of other arrangements of trussed girders will be better left until after the next lecture, as I shall then introduce to you a system of working by which your difficulties will so vanish that it may well be called the royal road to the determination of strains.

There are, however, a few cases of structures in which the strains are determined more easily by the parallelogram of forces than by any other method. Among these are all varieties of cranes, and as I have not yet seen any book which indicates the mode of finding the strains correctly, it may be desirable to give you a few hints about them.

In its simplest form, a crane is a projecting bracket, carrying a pulley, over which a rope or chain passes. If a crane of the kind shown in Fig. 102 have a load of 1 ton, the books say the strain will be tension = 1 ton, compression

$= \sqrt{2} = 1{\cdot}4$ tons, as in Fig. 103; but if we take this sketch as a sample, and apply the method without discrimination, we shall soon get into difficulty. In the first place, the load is not hanging direct from the end of the jib; it is hanging on the chain, and the chain has an equal tension in every part, and we have therefore two forces, as in Fig. 104, the resultant of which will pass through the sheave-pin, and give us a diagonal force as the actual connecting link between the load and the crane. With the chain leading off horizontally from the top of the sheave, and the load always hanging vertically, we shall find the effect the same as if the load were hanging direct from the sheave-pin, so far no error; but frequently the chain is not led horizontally from the top, and allowance should be made in many cases for pulling at the load with the chain out of plumb. So that practically we must take the direction of the chain for the top of the parallelogram, and the mean direction of the load for the side of the parallelogram. Then the remainder of the working will be a simple application of the principle that you have already had some practice in.

If we had taken an angle of 60° for the jib, the error of the common mode of working would have been very striking. Fig. 105 shows the arrangement, and enlarging the parallelogram of forces, as in Fig. 106, we find that the tension in the stays will be given as ·58 ton, and compression in jib 1·16 tons; whereas, taking the correct mode as in Fig. 107, or enlarged in Fig. 108, we find that both the jib and mainstay or tie rod are in compression, the amounts being respectively 1·16 tons and ·42 ton. The weight of the parts will affect the precise result, but not the principle. This shows how very careful one must be to take the exact course by which the strain is communicated from one part to another.

The subject of Cranes will form one of the lectures in the Advanced Course, which I propose to give as a sequel to the

present course; there is ample work for an evening in tracing out the various strains upon a few of the more typical forms, and I must not detain you longer with them now.

QUESTIONS FOR HOME-WORK.

1. Mark the amount of strain in each part of the following truss (Fig. 109), when the load equals 3 tons, omitting weight of truss.—Ans. See Fig. 110.

2. In the following girder (Fig. 111) mark the strains in each portion, taking the distributed load as 10 tons, including weight of girder. —Ans. See Fig. 112.

3. In the following girder (Fig. 113) distinguish the parts in compression by thick lines.—Ans. See Fig. 114.

LECTURE VII

The reciprocal diagram of forces—Explanation of the principle—General knowledge of strains necessary before use can be made of this system—Construction of diagram—Lettering spaces instead of lines—General directions for constructing diagrams—Application to roofs—Diagrams for single and double rafters—For span roof with tie rod—For same with addition of king bolt—For ordinary king-post roof truss—For roof with king and queen rods—For span roof with tie rod and double king bolt—For same with addition of struts—For same having additional ties and struts for larger span—For span roof with king bolt and cambered tie rod—For same with open king bolts—For trussed rafter roof—Examples.

We have seen how to find the strains in the simplest form of a roof truss, or trussed beam, by means of the parallelogram of forces, and you will remember that I mentioned the fact, that if any three forces in equilibrium acting on a point be represented by three lines of proportionate magnitude and corresponding direction, they could be so arranged as to form a perfect triangle; and any number of forces, under similar conditions, would form a closed polygon of the same number of sides.

Well, the converse or reciprocal of that statement holds good, and upon this is founded the system first introduced by Professor Clerk Maxwell, called the "Reciprocal diagram of forces"; which has been further elaborated by Mr. Bow, a civil engineer, and I have now to introduce it to you with a few applications of my own.

Briefly, the reciprocal relationship would be defined thus: corresponding lines which meet in a point in the one figure form a closed polygon in the other, but this is not always possible so far as regards lines representing external forces.

We will take a simple triangular truss to represent the method, and then you will better understand the directions which I shall give you for finding the reciprocal diagram in any given case.

Let Fig. 115 be the truss supported at each end, and, for sake of simplicity, loaded with a concentrated weight at the apex.

Now, in this system it is of vital importance to ascertain correctly the position and amount of all external forces; here we have three, I will indicate them by arrows (see Fig. 116). The next step is to letter each space within the trussing, and also each space outside the trussing, as in the figure.

Then, in the diagram, any line representing a portion of the truss, or a line of force external to it, will be named from the two letters belonging to the two spaces it separates.

Thus, draw C D (Fig. 117), in direction and magnitude equal to the load on apex; it is evident that the reaction on each support will equal $\frac{1}{2}$ C D, or C B + B D = C D, therefore place B midway between C and D. From C draw C A parallel to the left-hand rafter, and B A parallel to tie rod, meeting in point A; also D A parallel to right-hand rafter, when the figure is completed; and by measuring the length of any line in the diagram we obtain the strain acting in or upon the part separating the similarly lettered spaces in the truss. To make the diagram indicate as much as possible, the parts in compression should be thickened, and you will have no difficulty in doing this with your present knowledge, although the diagram throws no light upon this portion of the subject.

You will now be in a position to understand the detailed directions for constructing a reciprocal diagram for any other case.

1st. Assign a letter to each enclosed area of the truss, also to each division of the surrounding space as separated by the lines of action of the external forces.

2nd. The lines in the diagram are to be drawn parallel to the corresponding lines or parts of the truss figure.

3rd. The forces acting in lines radiating from a point in the truss must in the reciprocal diagram form a closed polygon.

4th. The sides of any uncrossed space, triangle, or other polygon, around or in the truss, must always be represented by lines radiating from a point in the reciprocal diagram, and that point is to be named by the letter assigned to the space or polygon.

5th. All the external forces acting upon a truss must, taken together, be represented in the reciprocal diagram by the sides of a closed polygon.

In the example we have taken above, the external forces, taken together, really form a closed polygon, but the sides overlie each other. If we open them a little, as in Fig. 118, we shall see this relationship better.

Although the principles are so simple, the arrangement of the diagram will sometimes be a troublesome matter until you have had considerable experience, and I therefore propose to give you sketches of some of the ordinary forms of roof trussing in ironwork, with the corresponding diagram fully lettered, and in fact ready for you to apply to any case that may arise in your practice.

We will start with our former illustration of the inclined beam, and divide the trussed examples into groups, according to the arrangement of the parts, assuming in every case a distributed load such as a roof has ordinarily to bear.

For a single rafter, as in Fig. 119, commence with the loads, taking the left-hand first, and if your sketch has been lettered properly and the diagram worked correctly, the letters on the diagram will come in regular order, as shown in Fig. 120.

For a pair of rafters we have the arrangement shown in

Fig. 121, with its diagram shown in Fig. 122,* and for the same with a tie rod we have Figs. 123 and 124. In this last diagram we have a clear illustration of what I have told you previously about the portion of the distributed load next the abutment being carried direct by the support, without transmitting any strain through the truss. Here you see the piece C D comes outside the lines showing the strains in the truss, indicating that it is dead load on the abutment only.

Now, if we put a king bolt in the same truss, as in Fig. 125, we shall find in Fig. 126 that it has no strain from the load, its sole duty being to support the tie rod. C A, C B are both horizontal, and must therefore be in the same straight line from C; but E A and F B are equal in length, start at equal distances from C, and make equal angles with E F, therefore A and B must be both at the same point; then the strain in A B being represented by the distance from A to B, it will be seen to be nil. Many other cases will occur in practice, in which you will find that, so far as the transmission of the load is concerned, there will be a redundancy of parts indicated by the letters, representing a line, meeting in one point. In other cases you may find that there will be an excess of parts giving a variable strain according as the load is assumed to be borne more or less by the different members; these latter are of course awkward instances, and belong to advanced practice.

Now we will add two struts to the truss, and try the result. (See Figs. 127 and 128.) In this case A and D come into one point, because the tie rod is straight; if it were cambered they would not come together.

Taking the same type of roof applied to a larger span, as

* In the lectures the whole of the illustrations were drawn on the blackboard, the diagrams being constructed line by line; it is hoped that the reader will find no great difficulty in tracing out for himself the order of working and the lengths of the lines with the lettering given.

in Fig. 129, we find, as we might have expected, that there is no strain in I J, or A B. (See Fig. 130.)

Now go back to Fig. 125 and split the king bolt so as to get two points of support for the tie rod, as in Fig. 131, and see what effect it has. We find by Fig. 132 that there is no strain in A B or B C due to the trussing, so that the only strain upon them will be due to the weight of the tie rod.

Let us add two struts, and we get the truss and diagram shown in Figs. 133 and 134.

Taking the same type of roof for a larger span, the additional trussing will be as shown in Fig. 135, and the diagram as in Fig. 136. In this form of roof the struts are sometimes arranged so as to be perpendicular to the rafters, and therefore in the best position for resisting the strain in them, because they are then of the minimum length. At other times they are arranged by dividing the tie rod equally and making the junctions with the tie rod at the points so found.

Next go back to Fig. 125 and camber the tie rod, as in Fig. 137; owing to the camber of the tie rod, we now get a strain in A B, as seen in Fig. 138.

Now follow on with Fig. 131 cambering the tie rod in the same way, as shown in Fig. 139, the diagram for which will be Fig. 140.

Take the same again with the addition of struts, as in Fig. 141, giving a very common form, and known as a trussed rafter roof. We may consider this as two separate trusses, united by a tie, as in Fig. 143: it is a very good form for small roofs.

In this system of diagrams you have a key to the elucidation of the strains in the most complicated structures, and I shall further exemplify its use in the next lecture by taking various forms of lattice girders.

Very careful working is necessary, and accurate parallelism between the lines of the diagram and those of the figure.

The examples for home-work upon the present lecture will form a very good test, both of your carefulness in this respect and of your general ability in applying known rules to modified cases.

QUESTIONS FOR HOME-WORK.

Work out the strains in the following trusses by means of reciprocal diagrams, and figure the values on the sketches:

1. Span 20 feet, load 4 tons distributed, camber of tie-rod 12 inches, rise $\frac{1}{4}$th that of span. See Fig. 144.—Ans. See Figs. 145 and 146.

2. Span 20 feet, load 4 tons distributed, camber 12 inches, rise $\frac{1}{4}$th of span. See Fig. 147.—Ans. See Figs. 148 and 149.

LECTURE VIII.

Application of reciprocal diagram to lattice girders—Diagram for Warren girder, with central load supported on top flange—For same with load on bottom flange—For same with additional bays—For same with distributed load on top flange—For same with load on bottom flange—For lattice girder, with bars intersecting at 45° under concentrated and distributed loads—For lattice girder with vertical bars—Examples.

This evening we shall apply the reciprocal diagram of forces to lattice girders of different kinds, and you will see how favourably the system compares with the ordinary parallelogram of forces for such investigations.

Very little explanation will be required; the chief difficulty is to know what form the diagram will take for each variety of girder or arrangement of bars. I will sketch them down, and point out any particular part requiring notice, and I hope you will stop me at once, if any part is not quite clear to you, in order that I may explain it.

We will take first a Warren girder of 3 bays, with a concentrated load in the centre on top flange, Fig. 150. In this diagram, Fig. 151, we have I J = full load, and I H, H J each = $\frac{1}{2}$ full load. There is no strain in I A or J G, which agrees with the result found by other methods.

But suppose we have the same load supported by the bottom flange instead of the top, as in Fig. 152. We now get considerable alteration in the strains, and find some difficulty in adjusting the lines showing the application of the external force or load. The weight is acting in the centre of middle

bay, but so far as the trussing is concerned, the load is divided between the points *a* and *b*, and we must therefore put lines here, each representing half the load, and then letter the spaces as shown. The letter K represents the whole exterior of the girder above the abutments, because there is no external force outside of the reactions upon the abutments. Then, in constructing the diagram Fig. 153, we shall find that as the load is on the bottom flange the whole diagram will be reversed, the truss strains being on the right of the lines of forces instead of on the left, and you see that C D, D E have no strain upon them, because all three letters meet in one point in the diagram.

Now take the first example again, and add half a bay on to each end, making 4 bays in all instead of 3, as in Fig. 154, giving the diagram in Fig. 155.

If the load were taken on the bottom flange of this girder, you would work it out in the same way as Fig. 152, but the diagram would be like Fig. 151 reversed.

Now take Fig. 150 again, and try it with a distributed load, Fig. 156, obtaining the diagram Fig. 157.

If you compare diagrams 151 and 157, you will see that with the same total load the strains are much smaller with the load distributed, shown by the area of the diagram being smaller when drawn to the same scale.

We will take the same girder again with a distributed load, but carried by the bottom flange, because we shall then discover a new difficulty. (See Fig. 158.) The difficulty is this: at each end of the girder next the abutment we want a line to indicate the portion of the distributed load carried by that point, and also a line indicating the reaction of the abutment, both lines being truly vertical, and meeting at the same point. In a case like this, the simplest way is to imagine the double line split open, giving room to put a letter between, as shown at L and H. Then I H will be the

OF THE
RSITY
ORNIA

load and H M the reaction, and the diagram will be as Fig. 159.

Next we will take a lattice girder, the bars of which cross each other in the centre of their length, and all incline at an angle of 45°, as in Fig. 160. It is very certain that, without being told, many of you would puzzle over this girder a long time before you would be able to satisfy yourselves about the strains, and you will most likely be astonished to see the number of theoretically useless parts, as proved by Fig. 161. Practically, the dotted bars would help to stiffen the others, and therefore be of some service, a bolt or rivet being put through their intersection.

Taking the same girder with a distributed load on the top flange, as in Fig. 162, we shall find by diagram Fig. 163, that all the bars but two are strained. Point A in the diagram will be midway between O and N.

Suppose we add vertical struts to this girder at each apex, giving Fig. 164, we shall then find by Fig. 165 that even with a concentrated load all the bars are under strain except two struts which are not underneath the load.

For the next example we will take the same girder, but with a distributed load carried by the *bottom* flange, Fig. 166. In this case, taking the letters in alphabetical order, W happens to come on top, where it represents the exterior space, not a load, and in setting off the loads in the diagram Fig. 167, we have some difficulty in finding point A. It is obtained thus: W V is half the load, from this subtract V U, which is the amount borne direct by the abutment; the remainder U W will be transmitted half through A B and half through A C, therefore place A midway between W and U. In this case we have a perfect girder, every part being under strain.

In applying reciprocal diagrams to the study of strains in bridges, great caution is required, owing to the magnitude

of the expenditure and credit at stake, and the difficulty in many cases of deciding the exact course of the strains. While the method is second to none for estimating the proportions in preliminary designs, precise calculations should be resorted to for the final sections and joints.

Many other structural forms might have claimed our notice, but as our time would only permit of examining a few leading varieties which could be treated in an elementary manner, I have selected those which I thought would be most useful to you, and I hope that you will be able to make practical use of the information you have derived here.

In conclusion, allow me to thank you most heartily for the interest you have shown in this comparatively dry subject, and particularly for the manner in which you have worked the home papers; although there have been numerous failures, there has on the whole been substantial progress. I always adopt the custom of giving questions for home-work, because it compels some attention to the subject between the lectures, and the answers enable me to gauge the ability of my hearers so that I may modify the future lectures if necessary; and, moreover, the pleasure of personal conference with my hearers is not the least of the advantages. In all probability the scheme inaugurated by the lectures now brought to a close will become a permanent feature of the Society of Engineers, and therefore any suggestions as to future subjects will be gladly received. I trust you will make these courses widely known among your professional friends, and I may say in response to numerous enquiries from those anxious to continue the study of strains, that I will endeavour to get an Advanced Course ready for next session, but my numerous engagements leave me so little leisure, that it may be some months before I can make a commencement. Cranes, gas-holders, lock-gates, bridges, arched roofs, and the effect of moving loads will form some of the subjects; and should any you

in the meantime discover any structure involving special difficulties, I shall esteem it a favour if you will communicate with me, in order that they may receive due consideration.

QUESTIONS FOR HOME-WORK.

1. A Warren girder, 20 feet span, has a concentrated load of 5 tons, carried as shown in Fig. 168. Indicate the nature of the strains and figure their value, omitting the weight of the girder.—Ans. See Figs. 169 and 170.

2. A lattice girder (as in Fig. 171) for bridge 24 feet span, 6 feet deep, weighs 4 tons, and carries a distributed load of 2 tons per foot run on bottom flange; show the nature of the strains and figure their value.—Ans. See Fig. 172, and for diagram see Fig. 167.

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS, LIMITED, STAMFORD STREET
AND CHARING CROSS.

LIBRARY

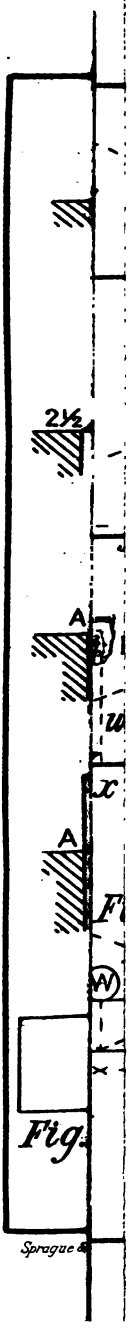


Fig.

Sprague &

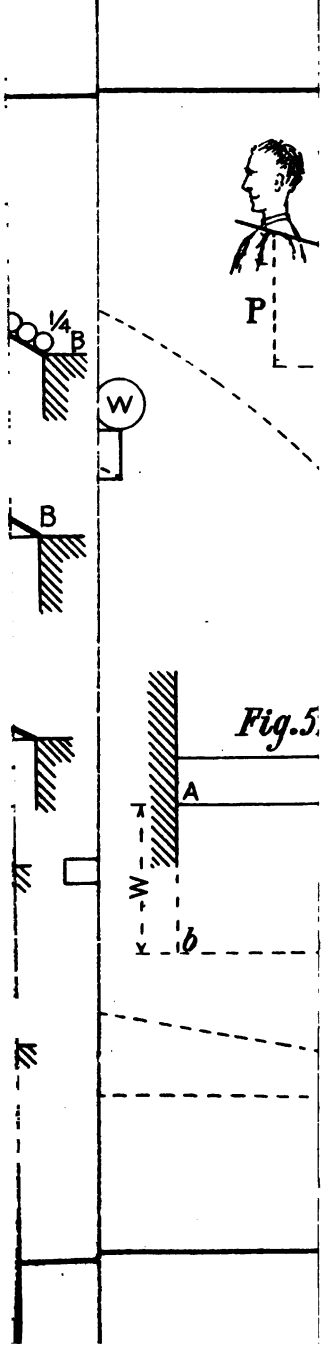
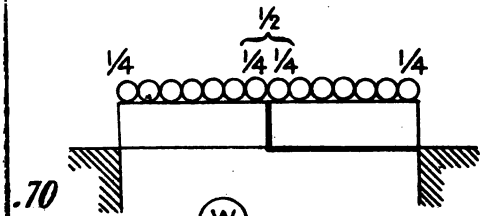
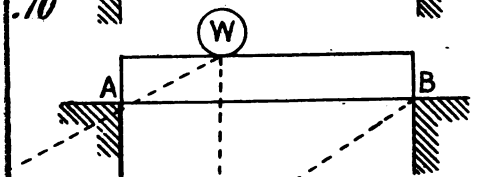


Fig.5



.70



.71

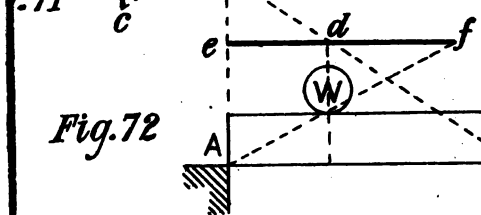


Fig. 72

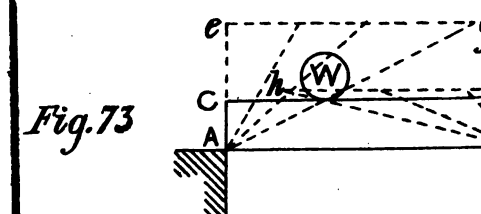
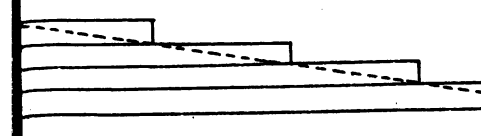


Fig. 73



E & F N. Spon, London & New York

UNIVERSITY

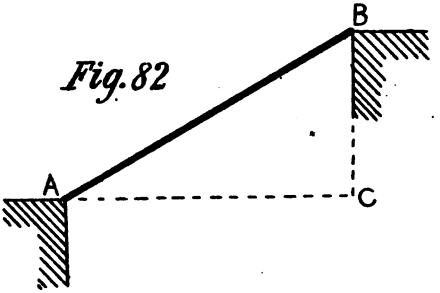


Fig. 82

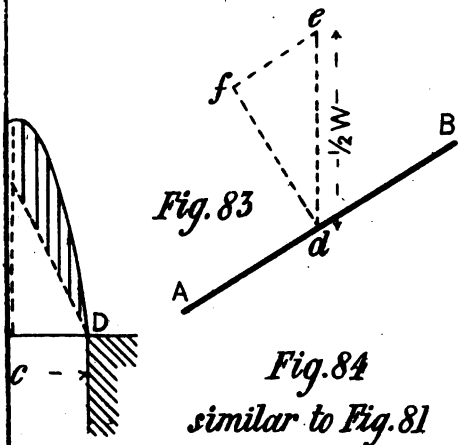
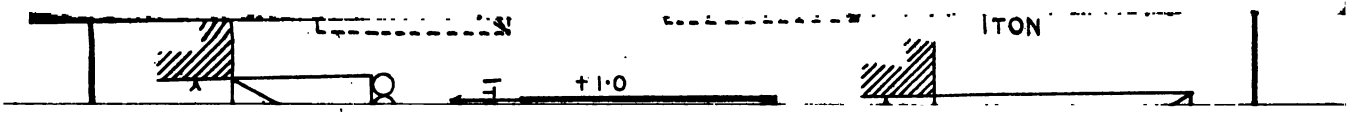


Fig. 83

Fig. 84
similar to Fig. 81
but to larger scale

E & F. N. Spon, London & New York.


1TON
+1·0

REESE LIBRARY
OF THE
UNIVERSITY

Fig.144

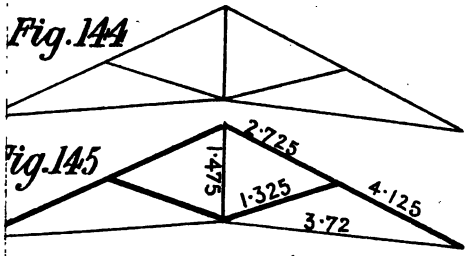
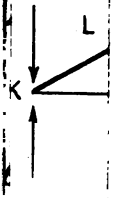


Fig.145



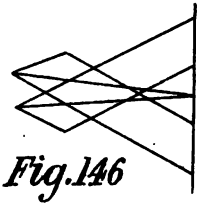


Fig.146

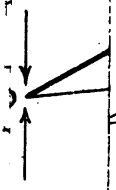


Fig.147

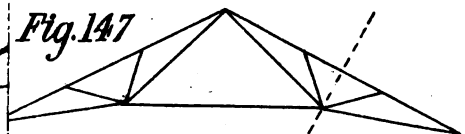
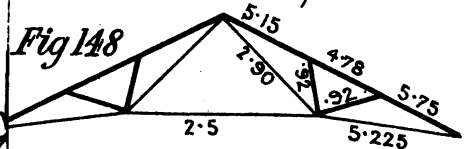
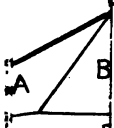


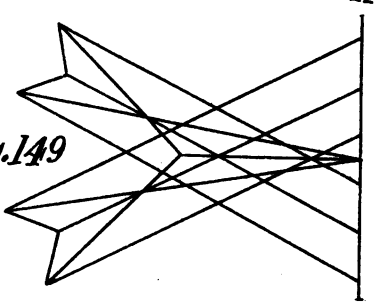
Fig 148





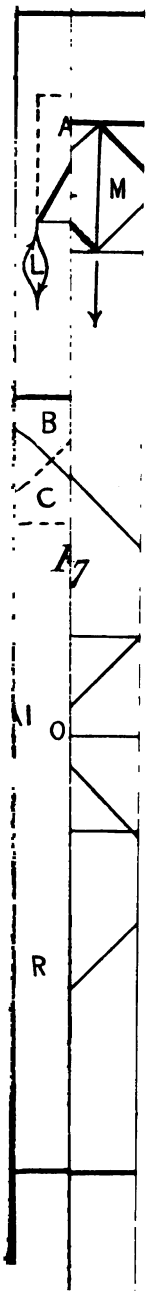
g.149

Fig



E. & F. N. Spon, London & New York

REESE LIBRARY
OF THE
UNIVERSITY
OF CALIFORNIA


A
M
L
B
C
O
R

THE CITY POLYTECHNIC.

City of London College,

WHITE STREET, MOORFIELDS, E.C.

FIFTY-FIRST ANNUAL SESSION, 1898-99.

SYLLABUS OF LECTURES IN THE

ENGINEERING DEPARTMENT.

PROFESSOR:

MR. HENRY ADAMS,

M. Inst. C.E., M. I. Mech. E., F.S.I., F.San.Inst., &c.

Past-president of the Society of Engineers.

Science Certificates: First Class Honours, First Place, 1869

Queen's Medallist in Science, and Certificated in Art.

WITH COMPETENT ASSISTANTS.

For Detailed Lists of College Prizes, Syllabus of Work in other Classes, Examination Papers, List of Associates, Members and Registered Students, and a variety of useful information see the "College Calendar" post free 9d.

IMPORTANT NOTICE.

Several of the students in the Engineering Department have obtained good appointments through the College, and employers have frequently expressed their satisfaction at the ability of those engaged by them. A Register is kept at the College in which students wanting employment may enter their names and addresses. Letters requiring a reply should enclose a stamped addressed envelope.

Former students are requested to make known among their younger friends the facilities for study afforded by the City of London College. There are now forty Professors and Lecturers upon the staff, giving instruction in upwards of 50 different subjects of Science, Art, Language and Literature, divided into 130 classes, and the attendances for the session (seven to nine months) average over 50,000. The handsome Building, erected at a cost of £16,000, contains accommodation of a superior character for 4,000 Students, and is situate within two minutes' walk of MOORGATE STREET STATION AND TRAMWAY TERMINUS, and within five minutes' of the Broad Street and Liverpool Street Stations and of the Bank. The classes are divided into various stages to suit the progress of students; and all the rooms are amply ventilated and lighted. In addition to the usual periodicals and newspapers, the Reading Room is provided with nearly all the Technical papers, and there is also a good Library.

To prevent the occasional overcrowding in some of the classes, the adjoining building has been taken on lease and fitted up for Art Studios and additional Lecture Rooms, with all the latest improvements.

All fees must be paid in advance at the College. The general Prospectus of all the Classes will be ready on the 1st September, and the College Calendar, price 6d. (post free 9d.) required by all students, will be ready on the 1st October.

Secretary.

Contents.

	PAGE
Time Table of Classes and Fees	4
Technical Drawing	5
Machine	6
Building Construction	7
Honours	9
Prizes for above Classes	10
Practical Sanitary Science	12
Sanitary Engineering	12
Civil Engineering	12
Mechanical Engineering	13
Surveyors' Institution	14
Quantity Surveying (Leaving)	15
Valuation (for Surv. Inst. Exams.)	16
Land Surveying (Surv. Inst.)	17
(General)	19
Theodolite Work	23
Engineering Field Work	25
Town Surveying	25
Laying-out Building Estates	26
Compass Traversing	26
Reading Room	27
Technical Library and Museum	27
Science Society	27
Notices of Meetings, Papers, &c.	27
Press Notices	28

TIME TABLE OF CLASSES, 1897-98.

		FEES		COMMENCING
		MEM.	NON-MEM.	
TECHNICAL DRAWING AND DRAWING OFFICE PRACTICE—				
Beginners	Wed. 6—7 p.m.	5/-	7/-†	28th Sept.
Elementary	do. 7—8 „	8/-	10/6†	„
Advanced	do. 8—8 „	12/-	15/-†	„
BUILDING CONSTRUCTION—				
Elementary	Mon. 5.30—6.45 p.m.	6/-	7/-†	3rd Oct.
Advanced	do. 6.45—8.0 „	8/-	10/6†	„
Honours	do. 8.0—9.15 „	12/-	15/-†	„
MACHINE CONSTRUCTION AND MECHANICAL ENGINEERING—				
Elementary	Fri. 7.0—9.0 p.m.	5/-	7/-†	30th Sept.
Advd. & Hon.	do. 7.0—9.0 „	7/-	10/6†	„
CIVIL ENGINEERING—	Thur. 7—9 „	7/6	10/6†	29th Sept.
VALUATION (SURV. INST.)—	do. 8—9 „	15/-	17/6†	
SANITARY ENGINEERING—	do. 8—9 „	15/-	17/6†	5th Jan.
QUANTITY SURVEYING (Leaning)—				
Mich. Term	Fri. 6—7	10/-	12/6†	30 Sept.
Lent „	do. do. „	12/6	15/-†	6th Jan.
LAND SURVEYING—				
(Surv. Inst.) Mich. Term	Thur. 6—7	42/-	45/-§	29th Sept.
(General) Lent „	do. 6—7 „	16/-	17/6§	6th Jan.
Field Work	Saturday Afternoons §			

Private Classes in Easter Term, *see p.* 23.

Drawing boards and tee squares provided free for use in the classes.

† These fees are per term averaging 12 lessons.

‡ These fees are for the whole Session, October to May inclusive. Students holding vouchers for any of the Construction Classes, will be admitted on Wednesday evenings without extra payment, to enable them to complete their home work at the College.

¶ Per course of twenty Lectures.

‡ Per course of ten Lectures.

§ See Syllabus, pages 21 to 31.

The MEMBERSHIP subscription of 10s. 6d. per annum dates from the 1st October, and includes free admission to the Libraries, Reading Rooms, Refreshment and Common Rooms of the Constituent Institutes of the City Polytechnic, and also admission to the classes, weekly lectures, and entertainments, at reduced fees.

Private lessons are given when desired in any subject of this Syllabus, and pupils received in office for general study. Fees according to subject and time.

SYLLABUS

Technical Drawing and Construction.

In connection with the Government Department of Science and Art.

The valuable text books on constructional subjects written by Mr. Adams afford evidence that the instruction given in these classes is practical and thorough.—BUILDING NEWS.

Under the guidance of Prof. Henry Adams, this department has been long and honourably known for the sound and thorough character of the education and training supplied.—PRACTICAL ENGINEER.

The class in Technical Drawing was instituted in 1874, for the purpose of training students in the principles and practice of Drawing applied to the Arts of Construction, to prepare them for entry into Engineers' and Architects' Offices, or to perfect them in their duties if already engaged in such an office. Students under sixteen are recommended to take this subject alone for one session, and then to take it in conjunction with Machine Construction Classes; neat draughtsmanship being the first essential to a proper study of Construction.

Students who are regular in their attendance will, under certain conditions, have the privilege of attending some of the meetings of the various professional societies. Application should be made to the Professor for cards of admission.

The following subjects, with a few exceptions, are represented by an elaborate collection of over 1,300 diagrams drawn by hand to a large scale, coloured, and fully dimensioned, in order that the students may prepare from them working or finished drawings. A new set of these diagrams is in course of preparation, a separate sheet, Atlas size, being given to each detail. Other subjects are discussed in the class lectures, and illustrated by hand sketches on the black board and also by models, and photographs. As far as possible a progressive and connected course of instruction is given, typical details being selected for fuller demonstration.

TECHNICAL DRAWING.—Instruments required—How to select them—How to cut the pencil points—Method of holding tee square—Mixing Indian ink—Effects in use of instruments—Laying on flat washes of colour—Primary and secondary colours—Practice in figuring and lettering—Practice in joining curves and lines—Meaning of the phrase "drawing to scale"—Scales of various proportions—Irregular figures and block plans for practice in drawing to scale—Copying plans by proportional squares—Scale for enlarging and reducing copies of drawings—Defects in instruments and how to remedy them—Drawing parallel lines by set squares only—Principles of shading—Shading by back line—Rule for back line—Shading by flat tints—Shading rivets and bolts—Simplest method of shading cylindrical surfaces—Shading by uniform and graduated lines—Complete shading of curved surfaces—Projection of shadows on flat surfaces—Table of colours to indicate various materials—Colouring for brickwork and concrete—Colouring for earthwork sections—Colouring for slate and tile roofing—Sectional shading in ink or pencil to represent various materials—Tinting and graining for fir and oak—Elevation of door-head in ornamental brickwork—Tile paving—Classic mouldings—Projection in vertical, horizontal, and profile planes—Projection of spiral line or helix—Screw thread—Vee and square thread screws—French curves—Construction of ellipse and parabola—Elliptical skylight—Elliptical brick arch over gateway—Elliptical stone arch—Angular projection—Projection of pulley at an angle—Isometrical projection—Construction of isometrical scales—Outlines of arches; semicircular, segment, equilateral, lancet, tudor, and ogee—Window tracery—Geometrical constructions—Conversion of French measures into English—Fluted pilaster and column—Entasis of columns—True elevation of skew arch—Proportional scale for enlarging and reducing—Practical perspective as used by architects—Artistic designs—Competition drawings—Drawing-office practice.

MACHINE CONSTRUCTION.—Transmission of power by shafting—Key and keyway—Journals—Belt pulley—Rolling and wrapping contact—Bushed bearing—Brass step—Box coupling for shaft—Half-lap and dovetail couplings—Footstep for vertical shaft—Open and crossed belts—Plummer block and brasses—Fly wheel—Crank pin—Wrought and cast iron cranks—Cranked shaft—Slotted link—Motion pin—Split pin and washer—Single and double eye—Forked end of small connecting rod—Bolts and nuts—Whitworth standard proportions—Spanner for tightening nuts—Box and claw spanners—Lock nuts—Various forms of nuts—Varieties of bolts—Gib and cotter connection—Ratchet wheel and pawl—Rack and pinion—Spur wheel and pinion—Riveting—Single and double riveted joints—Rivet heads, various forms—Lap and butt joints—Three-way and four-way cocks—Bib cocks—Mitre valves—Stuffing box and gland—Watt's parallel motion—Safety valve—Ramsbottom piston rings—Guide bars and cross head—Bucket for lift pump—Piston and ram for double acting force pump—Wrought-iron pump rods with coupling box and cotters—Wrought-iron solid flange coupling for screw shaft—Eccentric sheave and strap—Stuffing box with metallic packing—Slide

valve and cylinder face—Sun and planet wheels—Suction, lift, and force pumps—Butterfly valve—Mushroom valve—Flap valves—Clacks—Stop valve—Throttle valve—Eccentric cam—Principle of cam punching press—Angle iron and plate shears—Cams for producing uniform velocity—Heart wheel cam—Snail and bale cams—Eccentric cam with a velocity curve—Cylinder shears—Lathe driver and carrier—Face plate for lathe—Quadrant bracket for screw-cutting lathe—Crank centre for foot lathe—Dog chuck—Lathe bed—Speed pulley—Split drum—Flat-linked chain—Short linked crane chain—Stud chains—Chain shackle—Oval counter-weight for crane chain—Conveyance sheave for chain—Chain hook—Ram-horn hook—Stopping, starting, and reversing gear for shafting—Reversing gear for planing machines—Classification of cutting tools—Howlett's adjustable friction gearing—Robertson's friction gearing—Proportions of teeth for spur gearing—Manchester pitch—Cycloidal and epicycloidal teeth—Involute teeth—Willis' odontograph—Mitre wheels—Bevel gearing—Reversing gears—Quick return motions—Worm-wheel and screw—Screw cutting—To find change wheels for single and double trains—Skew gearing—Skew belt—Reversing gear by belts—Pillow block in wall—Hanging bracket for shafting—Various forms of keys, and methods of keying—Varieties of screw threads—Whitworth standard vee thread—American standard thread—Riveted joints, three and four plates over-lapping—Proportions of rivets in steam and watertight joints—Steam engine governor—Siphon, piston, and needle lubricators—Wilson's impermeator—Regulating valve and standard—Cowburn's dead-weight safety valve—Twin safety valve for boilers—Ramsbottom's safety valve—Gauge-cocks for boiler—Gauge-glass and fittings—Manhole and door—Boiler furnace—Parallel motions for land and marine engines—Link motions—Clutch coupling—Fowler's clip drum—Snatch head—Snatch block—Block tackle—Screw jack—Hydraulic jack—Screw propeller—Spiral and volute springs—Wrought and cast-iron girders and columns—Units employed in engineering calculations—Principles of leverage—Virtual velocities—Construction of velocity curves—Friction—Strains, tension, compression, torsion, shearing, bending, elasticity—Co-efficient of effect or modulus—Factor of safety—Indicator diagrams—Case hardening—Chilled and malleable cast-iron—Pattern making and moulding—Chief characteristics of various forms of Steam Engine and Boiler, &c., &c.

Honours Students in Machine Construction will be instructed individually

BUILDING CONSTRUCTION.—Joints in wood work—Halving, tenoning, mortising, dovetailing, mitreing, notching, cogging, fishing, scarfing, and tabling—Joints in flooring—Sections of ogee and other mouldings—Architraves—Ledged and braced doors—Varieties of framing, square framed, bead and butt, bead flush, moulded, and bolection moulded—Framed doors—Single, double and framed flooring—Wall plates and pole-plates—Various forms of roofs—Collar beam roof—King, queen, and

[illegible] roof timbers—Angle tie and dragon piece—Quarter partition—Bricknogging partition—Trussed partition—Lath and plaster—Framed partition—Bressumers and flitch girders—Handrailing—Dog-legged and open newel staircase—Details of sashes and window frames—Timber trenches and trenailes—Timber piles and pile shoes—Shoring and strutting—Strength of materials—Varieties and properties of timber, &c.

Process of building brick walls—Advantages of bonding—Bond in brick work, various thicknesses—Bonding returns and party walls—Bonding angles, buttresses, &c.—Grouting—Brick paving, flat and on edge—Plain, rough, and ganged arches—Brick piers—Sleeper walls—Brick tender—Door and window jambs—Wood bricks, plugs, and pallets—Footings and foundations—Damp-proof course—Concrete—Inverted arch—Discharging arch—Pocket for girder—Boundary walls—Dog's tooth moulding—Brick cornices—Raking courses—Barge and sailing courses—Corbelling out and gathering in—Brick chimney with moulded cap—Varieties of bricks—Hollow brick walls—Concrete walls and arches—Patent flooring and arches for fire-proof construction.

Ashlar facing—Ashlar quoin—Granite base for column—Rubble walling, uncoursed, random coursed, and coursed—Stone steps and landings—Curtail step—Spandrel steps—Cramps, joggles, and dowels—Stone copings; parallel, tilted, feather-edged, and saddle-backed—Stone corbels and templates—Window sills and string courses—Weathering and throating—Chamfering and splaying—Chimney-piece—Balconies—Cornices—Pediments and caps—Balustrades—Ransome's patent stone—Masons' putty—Precautions in bedding and fixing stonework.

Laying lead slats—Drip in gutter and lead rolls—Step flashing—Syphon traps to lead pipes—Bell trap—P trap—Draining and sanitary arrangements—Water service—Slating for roofs—Zinc roofing—Painting—Materials used—Knot prime and stop—Oil colours—Distempering—Whitewashing and limewhiting—Glazing—Crown, sheet, and plate glass.

Bolts, nuts, and washers—Tie bolts and straps—Gibs and cotters—Coach screws—Spikes, nails, and brads—Screw bolts—Wrought and cast iron sash frames—Air bricks and gratings—Rolled iron joist—Riveted joints—Wrought iron plate and box girders—Cast iron girders and springers—Cantilevers—Cast iron stanchions and columns—Wrought iron roof trusses—Wrought iron hand railing—Buttendy railing—Hawksley's, Lindsay's, and Hedges' patent treads—Corrugated iron roofing—Lattice girders.

Building Construction Honours.

A separate class is held for those students who intend sitting for honours at the May Examination. They should hold at least a Second Class Advanced Certificate, and will have to pass in the First Class of the advanced stage before competing in honours. Other students are allowed to attend this course, and it will be found useful in preparation for the Architectural Association, which they are recommended to join, for the Examinations in the Architectural Departments of the Admiralty, Office of Works, and War Department, also the Royal Institute of British Architects, the Society of Architects, the Carpenters' Co. and Sanitary Institute, the Association of Municipal Engineers, &c.

☞ **The only First-Class Honours-man in London at the 1893 Examination, was a Student in this Class.**

The foregoing Classes are all in connection with the Science and Art Department, and are placed at a low fee to enable artisans to avail themselves of the privileges afforded by the College. The numerous valuable Scholarships and Prizes detailed on the next page enable an industrious Student to obtain a free education of an advanced character and a large sum for the purchase of books, apparatus, &c.

PRIZES, &c.

In these classes the students are expected to make, within the hour, a complete pencil drawing to scale from a large diagram, the subject being so graduated in difficulty as to render this quite possible to all who attend regularly and keep up their practice. The drawings may then be inked in and coloured at home or in the Class for Drawing after Practice, the "finish" depending upon the time and ability at command. They are then collected, and at the close of the session sent to South Kensington for examination by the Art Department, when prizes are awarded to all who show good progress. The drawings are finally returned to the students at the commencement of the ensuing Session.

By the system adopted at the City and Guilds College it will be found that the Students are sufficiently prepared for the various examinations, while they are rendered really efficient Assistants to Engineers, Architects and others. The successes at South Kensington Science Examinations alone, including the Honours Stage, averaged over 90 per cent. from the formation of the classes in 1869 up to 1892, while the average successes of the United Kingdom in 1890 were Elementary 77 per cent., Advanced 84 per cent., Honours 37 per cent. Since 1892 the standard of the examinations has been considerably raised, but the College still leads in the list of successes.

TEXT-BOOKS.—TECHNICAL DRAWING AND ALL CLASSES: Adams "Class Notes," with Note-book and parcel, 6d.

MACHINE CONSTRUCTION:—"Low's Machine Design" (Longmans 2s.) and Adams' "Key to Examinations in Machine Construction" (Elementary) 2s. 6d., for Elementary Students; "Unwin's Machine Design" (Longmans, part I. 6d.) and Adams' "Key to Examinations in Machine Construction" (Advanced) 2s. 6d. for Advanced Students; Adams' "Handbook for Mechanical Engineers," 7s. 6d., and Kennedy's "Mechanics of Machinery," for Honours Students.

BUILDING CONSTRUCTION:—Burrell's "Building Construction" (Longmans 2s. 6d.) and Adams' "Key to Examinations in Building Construction," 4s. for Elementary Students; "Advanced Building Construction" (Longmans, 4s. 6d.) and Parker's "A B C of Gothic Architecture," 3s. for Advanced Students; Adams' "Strains in Ironwork," 5s., Adams' "Designing Ironwork," 8s. 6d., and "Notes in Building Construction," vols. I. to IV. for Honours Students.

In each case the more advanced classes should be acquainted with all the books recommended to the preceding classes.

Drawing-boards and T-squares are provided free, other drawing materials may be obtained in the Classes at the usual prices. The text-books named above may also be obtained at a discount of 2d. in the shilling.

PRIZES, &c.

For conditions of competition and further particulars see the College Calendar:—

The **ASSOCIATESHIP** of the **CITY** of **LONDON COLLEGE**, conferred after three years' successful study, upon application to the Governing Body.

The **CITY OF LONDON COLLEGE STUDENTSHIPS** of £3 3s. in Civil Engineering and allied subjects, and £3 3s. in Mechanical Engineering and allied subjects.

The **"LUBBOCK" SCHOLARSHIP** of £10 awarded on the result of the annual examinations, of which these subjects form a part.

COLLEGE PRIZES of £1 in each subject and **CERTIFICATES** of three grades.

The **"ADAMS" PRIZES** of £5 5s., £2 2s., and £1 1s. in Building Construction; and £1 1s. in Machine Construction. One of the prizes in each of the subjects is limited to first year students.

The **"MEDHURST" PRIZE** of £3 in Books, for regular and punctual attendance.

QUEEN'S BRONZE MEDALS to all who obtain places in First-Class Honours at the Examinations.

QUEEN'S PRIZES value £2 each, to a limited number of those obtaining First-Class certificates in the advanced stage at the May Examinations, who have previously passed in the elementary stage.

NATIONAL COMPETITION MEDALS and BOOKS for special excellence in Mechanical and Architectural Drawing.

ART PRIZES value 10*l.* each for meritorious sets of Drawings, and also for single works of special merit.

Four **ROYAL EXHIBITIONS** giving free admission to the Royal College of Science for three years with an allowance of £50 a year.

Twenty-two **NATIONAL SCHOLARSHIPS** giving free admission to the Royal College of Science for three years with an allowance of 30*s.* a week during the session.

Six **FREE STUDENTSHIPS** giving free admission to the Royal College of Science for three years but without any allowance for maintenance.

100 EVENING EXHIBITIONS in Science and Technology of the annual value of £5 each tenable for two years.

Four **WHITWORTH SCHOLARSHIPS** of £125 tenable for three years, and thirty **EXHIBITIONS** of £50 tenable for one year, to the most successful students in the May Examinations.

ROYAL ALBERT SCHOLARSHIPS of £50 per annum for three years, and free instruction at the Royal School of Mines.

INDUSTRIAL FREE STUDENTSHIPS for study at South Kensington Museum, Library, and Schools, for periods of from two to nine months. Detailed rules on application to the Department of Science and Art.

FREE ADMISSIONS to the Educational Libraries and Museums at South Kensington and Bethnal Green, to all Students who pass in the Advanced Stage of either subject.

Since 1860 *the students, under* MR. ADAMS, *have taken at the* MAY SCIENCE EXAMINATIONS:—2 *Whitworth Scholarships*, £100 *per annum*; 3 *Whitworth Exhibitions of* £50; 1 *Royal Exhibition of* £50 *for three years*; 1 *Free Studentship*; 1 *Queen's Silver Medal*, 3 *Bronze Medals*, 55 *places in Honours*, 215 *Queen's Prizes*, 417 *First-Class Certificates*, 569 *Second-Class Certificates*, *and* 100 *Elementary Passes*. *They have also obtained in the Examination of Drawings*:—*National Competition*, 2 *Bronze Medals*; 2 *National Book Prizes*, 39 *Third Grade Prizes*, 127 *Second Grade Prizes*, *and, up to* 1886, 214 *Awards of Marks equivalent to Honorable Mention*. *They have gained, in addition, a large number of College and Special Prizes and Certificates.*

Sanitary Engineering.

A course of 20 lectures on Domestic Water Supply, House Drainage, Ventilation and Heating, with special reference to Construction work, is given after Christmas on Thursday evenings at 6.30 p.m.

This course is especially adapted to the requirements of the Municipal and County Engineers, the Sanitary Institute, the Sanitary Certificate of the Surveyors' Institution, and the combined examination of the Carpenters' and Builders' Institutions.

It is intended to enlarge the scope of the Lectures to include Town Water Supply, Main Sewerage, and Sewage Disposal.

Civil Engineering.

This class is devoted to the principles and practice of Civil Engineering, but much of the work is closely allied to the subjects in the Honours Division of Building Construction, and many students may find it desirable to attend both classes.

The full course extends over three years, but each year is complete in itself; it will be found useful preparation for the examinations of the Institution of Civil Engineers, Engineering Departments of the Admiralty, Office of Works, War Department, &c., and Association of Municipal and County Engineers, and others.

The home work is an important feature of the system adopted at the College, helping to fix upon the memory the methods of procedure in designing, and the principles upon which it depends. Students are expected to bring some home work each week in answer to the questions which are set upon the subject of the lectures.

At the commencement of the Session the students select by ballot the subjects to be dealt with in the lectures, so that the instruction may be adapted to the needs of those attending. Amongst the subjects are the following:—

Foundations—Shoring and Underpinning—Coffer-dams and Piling—Embankments and Retaining Walls—Culverts and Sewers—Waterworks, Reservoirs and Dams—Fixed and movable Bridges—Lock Gates—Piers and Jetties—Canals, Roads and Railroads—Arches and Viaducts—Tunneling and Well-sinking—Chimney Shafts—Girders, Columns and Stanchions—Iron Roofs—Roadmaking, &c.

TEXT BOOKS:—Law's Civil Engineering; Adams' Strains in Ironwork; Adams, Designing Ironwork (1st Series, Spon 8s. 6d.)

BOOKS FOR REFERENCE:—Rankine's Civil Engineering; Wray's Theory of Construction; Walmisley's Iron Roofs; Fiddler's Bridge Construction.

Mechanical Engineering.

In connection with the City and Guilds of London Institute.

Prof. Silvanus P. Thompson, Principal of the City and Guilds Technical College, Finsbury, says:—

"The City of London College is not only doing admirable work in its literary and scientific classes, but has a capital engineering class."

* * The class in which Mechanical Engineering is taught by Mr. Henry Adams is highly popular.—*Daily News.*

THE Course of instruction and the Examination, will be founded upon such subjects as the following, but will not necessarily be confined to these subjects:—

EXAMINATION RESULTS

1. Practical shopwork and processes. Operations of tempering, welding, riveting, etc. Pattern making, moulding and foundry work. The use of the ordinary machines of an engineer's shop. Fitting shop work, including scraping and the use of gauges. Marking off. Erecting.

2. The steam engine and boiler, stationary, marine and locomotive; general questions as to design, arrangement, management and working. The construction and use of the most common engine and boiler fittings, including the steam engine indicator.

3. Pumps and pumping engines, including the Cornish engines. Pump valves. Centrifugal pumps and turbines. Water pressure engines and hydraulic machinery in general.

4. The design and proportion of the simpler machine details, including the making of freehand dimensioned sketches, roughly to scale. Mechanisms—means of obtaining and transmitting special motions in machinery. Spur and other forms of toothed gearing.

5. The strength and other properties of the principal materials used in engineering:—cast and wrought iron and steel, gun metal, brass, etc. Elementary consideration of the strength of ties, struts, shafts and beams, and the methods of coupling or joining most suitable for each case. Ordinary shop tests for the strength and quality of materials.

TEXT-BOOK REQUIRED:—Adams' "Handbook for Mechanical Engineers," 7s. 6d.

BOOKS RECOMMENDED FOR REFERENCE:—Shelley's "Workshop Appliances," Box's "Strength of Materials," Unwin's "Machine Design," Smith's "Cutting Tools," Fairbairn's "Millwork," Maginnis's "Hydrostatics," Wormel's "Thermodynamics," Perry's "Steam" Rankine's "Steam Engine," Wilson" "Steam Boilers," Spreteon's "Casting and Founding," Knight's "Mechanician" Molesworth's "Pocket Book," Seaton's "Manual of Marine Engineering," Rigg's "Steam Engine," Barber's "Engineers' Sketch Book."

These books may be consulted at the Patent Office Library, which is open free till 10 p.m. every evening.

NOTE.—During the ensuing session this subject will be combined with Machine Construction on Friday evenings for a single fee.

Surveyors' Institution.

EXAMINATION RESULTS

Obtained by Students of the City of London College.

In the 1884 Examination, £15 15s. Prize and 4 places. In 1885 the £15 "Institution" Prize and £15 "Driver" Prize, and 9 places, including the first in each sub-division. In 1886 the £15 "Institution" Prize, and 10 places. In 1887 the £10 10s. Prize and 12 places. In 1888 the £15 15s. Prize and 17 places, including half the successful candidates in the Building sub-division, and one-third of those in the Valuation sub-division. In 1889, the £10 10s. Special Prize and 14 places, including 4 out of the 9 Fellowships. In 1890 the £15 "Institution" Prize and 21 places, including 6 Fellowships. In 1891, 15 places. In 1892, the £10 Crawter Prize and 22 places, including 9 Fellowships. In 1893 the £15 "Driver" Prize and 14 places, including 5 Fellowships. In 1894, the £15 15s. "Institution" Prize and 13 places, including 4 Fellowships. In 1895, 17 places including 10 Fellowships. In 1896, 9 places including 4 Fellowships. In 1897, the £15 "Driver" Prize, and Penfold Silver Medal with 8 places, including 1 Fellowship. In 1898 the Penfold Gold Medal with 11 places, including 6 Fellowships.

Quantity Surveying.

IN PREPARATION FOR THE

SURVEYORS' INSTITUTION EXAMINATIONS.

ELEMENTARY COURSE.—MICHAELMAS TERM.

In this course of ten Lectures sufficient information is given to enable students to get a practical grasp of the subject. They are instructed in the methods of squaring and abstracting the meaning of technical terms, and the modes of measuring in each trade.

ADVANCED COURSE.—LENT TERM.

This Course of Ten Lectures is given with a view to complete the preparation of Students for the Examination in Quantities of the Surveyors Institution. It will deal with Quantities in accordance with the best London practice of professional Quantity Surveyors.

Students should have a practical knowledge of Building Construction equal to, at least, the Elementary Stage of the Science Examination. Questions and sketches for home work are supplied to practise students in taking off and billing quantities in proper form. The answers to be given upon properly ruled paper, and each item to be priced at correct rates.

TEXT-BOOK REQUIRED:—Leaning's "Quantity Surveying" (Spon), 15s.

RECOMMENDED FOR REFERENCE:—"Notes on Building Construction," Vol. I., 10s. 6d.; Vol. II., 10s. 6d.; Vol. III. 21s.; Laxton's "Price Book," 4s. 6d.; Banister Fletcher's "Metropolitan Building Acts," 6s. 6d.; "Estimating" (Bataford) 6s. 6d.; Seddon's "Builders' Work," 16s. Leaning's "Set of Contract Documents" (Spon), 5s. Leaning's "Specifications" (Sampson, Low) 4s.

A Prize of £1 1s. will be given by the Governing Body of the College to the student who, having regularly attended the lectures of the current session, passes the best examination. Certificates of three grades will also be awarded.

SPECIAL COURSE OF LECTURES

Valuation,

SPECIALLY ARRANGED FOR THE SURVEYORS' INSTITUTION EXAMINATIONS.

LECTURE 1.—Principal uses to which valuation tables may be applied—Nature of assistance afforded by them—Appraiser's licence, when required by Surveyor—Stamping awards—Examples of valuations—Sinking fund—Why various rates of interest are taken—Difference in value between freeholds and leaseholds for 99 years.

LECTURE 2.—Market rate of interest on various classes of property—Years' purchase—Nominal interest and actual interest—Relative value of covered and uncovered land—Agricultural land—Accommodation land—Building land—Land sales—Selecting land for development—Corner plots—Examples of valuations.

LECTURE 3.—Redemption of land tax—How price is fixed—Tithe commutation rent charge—How valued—Relative cost of land and buildings—To ascertain approximate cost of buildings by various methods—Actual cost of Buildings—Division of houses into classes—Example of valuation of land under various conditions.

LECTURE 4.—Terms for which leases are usually granted—Crown lands—City of London leases—Proportion of ground rent to rack rent—Improved ground rent—Joint ground rents—Advances to builders—Legal charges and stamps on conveyances and leases—Deductions from gross value for net annual rent—Percentage amounts—Allowance for dilapidations—Example of valuation where dilapidations have accrued

LECTURE 5.—Rental depending upon cost—Apportioning rents—Rental on three years' agreement—Formation of premium—Valuation of improvements—Sitting out of virtual rent—Gross estimated rental and rateable value—Deduction from gross value for rates and taxes—Examples of mixed valuations.

LECTURE 6.—Difference between granting a lease and renewing a lease—Fine on renewal—Renewal of Ecclesiastical and Crown leases—Examples of renewals of leases and valuation of same—Nominal increase of rent on renewal—Conversion of leaseholds into perpetuities—Reversions—Properties advertised for sale at fixed price to return high percentages.

LECTURE 7.—Life tables—Comparison of Northampton, Carlisle, Government, London, and Registrar General's tables—Value of life estate with or without life policy—Annuities—Different tables used when purchasing and when granting an annuity—Leases held on lives—Joint lives—Corresponding leasehold terms—Expectation of life in absence of table.

LECTURE 8.—Leasehold term corresponding to life interest—Comparison of leases on single lives and joint lives—Reversion after a given life of a lease for a term—Examples of reversions to estates held on lives—Renewals of leases for lives—Tables used by life assurance offices for premiums and annuities—Estimating premiums—Valuing next presentation to ecclesiastical benefices.

LECTURE 9.—Valuing shop property—Goodwill—Valuing public houses—Compulsory sales—Severances—Allowances.

LECTURE 10.—Analysis of mart sales—Probable market price—Rate of interest—Reserve price.

TEXT BOOKS.—"The Tables in Hurst's Architectural Surveyors' Handbook" (Spon, 4s. 6d.), "Macer's Dilapidations" (St. Bride's Press, 5s.), "Tarbuck's Handbook of House Property" (Lockwood, 3s. 6d.)

Compensations, Enfranchisements, Parochial Assesments, and other special branches by private tuition when desired.

SPECIAL COURSE OF LECTURES AND FIELD-WORK

IN

Land Surveying and Levelling,

INCLUDING ADVANCED WORK

IN PREPARATION FOR THE

SURVEYORS' INSTITUTION EXAMINATIONS.

We are glad to see that the class of this able lecturer is so well attended, as we are in a position to speak of the soundness and clearness of his instruction.—LAND AGENTS' RECORD.

Mr. Adams has long enjoyed a wide reputation as a first-class lecturer and instructor, and very many members of his classes have met with great success.—ESTATES GAZETTE.

In this course the work is summarised, so that the whole ground may be covered in about ten weeks, from October to December. It is more especially addressed to the requirements of the Syllabus of Examinations of the

Surveyors' Institution and the Auctioneers' Institute, and is adapted to those students who have already some knowledge of the subject. Others are recommended to take the General Course detailed in the next Syllabus. The lectures are illustrated by over 100 large scale diagrams specially drawn and coloured, and the number of instruments used in the field is suited to the attendance, all students obtaining a fair share of practice.

Theodolites, Levels, and other instruments are lent to students for private practice at a moderate charge.

LECTURE 1.—Principles of Land Surveying—Application of practical geometry and mensuration—Standards of measurement—Measuring instruments—Calculating areas—Tabulating the working—Plotting and use of scales—Base lines—Magnetic bearing and true north—Tie and check lines—Gunter's chain and arrows—Station poles—Field books—Offsets and offset staff—Area of offset piece—Examples for entry in field book and plotting.

LECTURE 2.—Mode of surveying for area only—Inset pieces—Give and take line—Optical square and cross staff, construction and use—Line ranger—Nature of boundaries, how shown on plan—Obtaining area by equalising lines, dividing plot up into triangles—Examples for plotting and calculation.

LECTURE 3.—Typical outlines of chain surveys for open land, woods, lakes, &c.—Representation of trees upon plans—Obstructions to continuations of chain line—Measurement of gap—Areas by computing scale—By Planmeter—Field notes of chain lines (without offsets) from several surveys.

LECTURE 4.—Various systems of projecting plans and maps—Ordnance survey—Surveying over hilly ground—Correction for inclination, how made—Indication of hilly ground on plans—Hachures and contour lines—Clinometer—Setting out drainage of new estate—Preparation of plans for Tithe Commission—Field notes of survey of small estate.

LECTURE 5.—Definition of levelling—Datum line, level line, horizontal line—Description of Gravatt's Dumpy level, Builder's Dumpy, Y level—Temporary and permanent adjustments—Level staff—Curvature and refraction—Simple and compound levelling—Questions for home work.

FIELD LESSON 1.—Chain surveying—Throwing chain—Setting station poles, ranging lines—Taking bearing with pocket compass—Prismatic compass—Chaining lines—Use of offset staff—Tape—Cross staff—Optical square—Box Sextant—Whites.

LECTURE 6.—Bench marks—Ordnance datum—Trinity datum—Ordnance survey maps—Level book—Field columns and plotting columns—Reducing levels—Checking each page by totals—Field notes and remarks—Plotting sections—Reflecting levels—Contouring—Rough levelling with Aneroid Barometer.

FIELD LESSON 2.—Chain surveying on hilly ground—Use of Surveyor's card—Protractor and plumbob—Drainage level—Clinometer—Stepping with Chain—Chaining past obstructions—Setting out right angle with chain—Use of common reflecting level—Abney's reflecting level—Aneroid Barometer.

LECTURE 7.—Angular measurement—Vernier scale—Construction and adjustment of Box sextant—Transit theodolite—Everest theodolite—Mode of taking horizontal and vertical angles—Questions for home work.

FIELD LESSON 3.—Levelling—Time practice in setting up and adjusting Level—Reading Staff—Taking running levels with approximate section of route—Ordnance bench marks—Minus readings—Third decimal—Comparison of totals.

LECTURE 8.—Cases in which the theodolite is useful—Surveying by the compass bearings—By the back angle—By two stations—Enlarging a base line—Field notes for plotting.

FIELD LESSON 4.—Theodolite work—Setting up and adjusting Theodolite—Taking bearing—Reading horizontal and vertical angles—Setting up over a given station—Taking angle between two lines—Traversing with Theodolite.

LECTURE 9.—Copying plans by pricking through, and transfer—Enlarging and reducing by proportional squares—Use of Triangular and Proportional compasses—Use and adjustment of Eidograph and Pantagraph—Ordnance Maps.

LECTURE 10.—Compass Traversing—Railway Curves—Marine Surveying.

FIELD LESSON 5.—(at 60, Queen Victoria Street, on the Saturday preceding the Surveyors' Institute Examination). Practical use and adjustment of Vernier protractor, Computing scale, Planimeter, Eidograph, and Pantagraph—Further inspection of instruments used throughout the course.

SHORT ADDITIONAL COURSES

IN

MENSURATION, TRIGONOMETRY AND TIMBER MEASURING

WHEN DESIRED.

GENERAL COURSE OF LECTURES AND FIELD-WORK

IN

Land Surveying and Levelling.

Part I.—CHAIN SURVEYING. (Ten Lectures).

LECTURE 1.—Introduction—Scope of lectures—Origin of the term Geometry—Distinction between theoretical; or pure geometry, and practical or applied geometry—Principles upon which Land Surveying is dependent—Difference between old system of surveying and modern

systems—Objects in view in measuring land—Distinction between office and field work—Six selected problems in practical geometry—Linear measurement—British standard of length—Unit adopted varies in certain cases—Table of Linear measures—Square measure Unit adopted in measuring land—Table of square measures. Form of working in calculating areas—Pointing off—Rule for area of rectangular figure—Example—Rule for area of triangular figure when base and perpendicular are given—Example—Rule for area of triangular figure when sides only are given—Example—Rule for area of four-sided figure, having two sides parallel—Example—Irregular four-sided figure divided into two triangles by a diagonal—The same divided into two triangles and a trapezoid—Example—Method of tabulating the working—Drawing to scale or plotting—Description and use of chain scale—Decimal system.

LECTURE 2.—Use of measuring tape—When desirable—Precautions to be observed—How angles are obtained—Practical example—Tie and Check Lines explained—All work must have tie lines, and the principal parts check lines in addition—Rule for distance of tie line from angle—How tape measurements are recorded—Gunter's chain—General description of its use—Field book, how used—Measurement of straight-sided fields and plots by base and perpendicular of component triangles—Use of station poles—How chain lines and stations are indicated in field book—Offsets—How measured and recorded—Various methods of obtaining perpendiculars—Practical illustration left for field course—Construction of optical square—Entries in field book—Bearing of base line—True north and magnetic meridian—Variation of compass—North point on plans—Examples of straight-sided fields from field notes.

LECTURE 3.—Importance of offsets being correctly measured—No check upon them as upon chain lines—Secondary lines of survey should approximate to all boundaries and divisions—Length of offsets—Offset staff—Order of working in plotting from field notes—Use of offset scale—Character of outline for boundary—Area of offset piece—By tabulating area of space between each offset—By geometrical casting—Example—By equalizing line on tracing paper—Example—Equidistant offsets, when used—Ordinary rules for calculating area—Improved rule and formula—Example—Double offset piece—How calculated—Example.

LECTURE 4.—How various boundaries are marked—Boundary stones, plates and marks—Building plots—Party walls, hedges and ditches—Why hedge is on inner side of ditch—Allowance for width of ditch—Fence boundary—Nails driven home—Marking owner's side on plans—Conventional signs—Office plans and finished plans—How each is prepared—Estate in detached portions, how plotted—Colouring and lettering plans—Colours for various objects and materials—Marking areas on plans—Surveying a three-sided field—Laying out chain lines by station poles—Check line—Order of measuring lines—Example.

LECTURE 5.—Chain lines outside any portion of field when better lead can be obtained—Caution in taking area by calculation when any inset pieces occur—Numbering the lines, usual plan in chain surveying instead of lettering stations—Irregular four-sided field—Example—Station not necessarily at commencement of line—Chain lines—Tie and Check lines—A, K, and X systems of lines—Hedge crossing chain line, how shown in field book—Post and rail fence—Open pale fence and close boarded fence, how shown on plans—Hedge, how shown—Colour of hedge.

LECTURE 6.—Selecting and marking stations—Sighting through or ranging the poles—Station not necessarily at extremity of chain line—Sheds and unimportant buildings taken by offsets and sketch in side column—Chain line crossing road and footpath—Auxiliary stations marked by whites—Irregular five-sided field—Example—Importance of neat draughtsmanship—Traversing with chain—Methods of tying angles.

(Field Work commences here.)

LECTURE 7.—Typical outlines of chain surveys—Check lines essential unless chain lines entirely check each other—Continuation of chain line often available as a check—System of lines when the area alone is required of that part surveyed—Field notes of chain lines (without offsets) from several surveys.

LECTURE 8.—Surveying woods, lakes, marshes, standing crops, &c.—Chaining outside boundary involves more difficulty than inside, because of hedges, fences, ditches, &c., to cross—Typical chain lines for surveys outside boundary—Example of survey of a lake—Plotting and colouring—Examples of a survey of a wood—Representation of trees of various kinds—Clumps of underwood.

LECTURE 9.—Obstruction to continuation of chain line—Setting up perpendicular with chain—Property of triangle having its sides in the proportion of 3, 4, and 5—Setting up angle of 60° with the chain—Method of working when obstruction does not impede the view, as a lake, stream, &c.—Another method—Additional precaution when the view is obstructed—To measure the distance of an inaccessible point width of river, &c.—To continue chain line across river—Method with cross staff—Examples.

LECTURE 10.—Plans and maps—Various systems of projection—Curvature of the earth not taken into account in ordinary surveys—Ordnance survey maps—Surveying over hilly ground—Correction for inclination—Why necessary—Table of reduction in links for various angles of inclination—Mode of indicating hilly ground on plans—Direction of hachures—Contour lines—Notes from instructions to surveyors for the preparation of plans for the Tithe Commission—Field notes of survey of small estate, to be plotted.

Part II.—CHAIN SURVEYING (Five Field Lessons).

Commencing after Lecture 6, Part I.

FIELD LESSON 1.—Throwing chain—Setting station poles—Ranging line—Taking bearing of base line—Use of cross staff—Use of optical square—Measuring portions of field staked out in straight-sided plots—By base and perpendicular—By boundaries and tie lines—Marking secondary stations by whites.

FIELD LESSON 2.—Laying offset staff perpendicular to chain—Measuring offsets—Long offsets hand over hand—Recording surrounding objects in offset column of field book—Connecting adjacent offset pieces—Traversing with the chain.

FIELD LESSON 3.—Survey of lake—Setting out stations—Tie and check lines—Insets to margin—Position and size of island obtained by tangents from stations—Junction line to second pond.

FIELD LESSON 4.—Survey of open land intersected by footpaths—Parish boundary—Offsets taken by tape—Setting up right angle with the chain—Chaining past obstructions—Detours, various modes.

FIELD LESSON 5.—Surveying on hilly ground—Judging rise or fall—Taking same by protractor and plumbob—Ditto by surveyor's card—Ditto by drainage level—Ditto by clinometer compass—Stepping with chain—Survey of portion of hill including boundaries and footpaths.

Part III.—LEVELLING (Two Lectures and Three Field Lessons).

LECTURE 1.—Introduction—Definition of levelling—Datum line—Distinction between level and horizontal—Definition of a level surface—Description of Gravatt's Dumpy Level—Adjustments and mode of using—Description of sliding staff—Effect of curvature of earth—Correction for this—Correction for refraction—Apparent height and actual height—Formula for reduction of any given observation—When corrections are necessary, and how avoided—Error from omission not appreciable in ordinary sights—Simple and compound levelling.

LECTURE 2.—Ordnance survey maps—Ordnance datum—Trinity datum—Levels—Bench marks—Flying or running levels—Check levels—Final levels—Main section—Cross sections—Field notes in level book—Back, intermediate, and fore sights—Rise or fall—Reduced level—Height above base—Checking by totals—Allowable error—Distances—Correction for inclination, when required—Plotting sections.

FIELD LESSON 1.—Time practice in setting up and adjusting level—Reading staff—Short and long sights—Ordnance Bench marks—Practice in taking flying levels and returning to same point.

FIELD LESSON 2.—Taking running levels with approximate section of route—Distances obtained by pacing—Minus readings—Third decimal, how dealt with—Comparison of totals, each student entering his own reading.

FIELD LESSON 3.—Main and cross sections—Working levels.

The field work is taken on Saturday afternoons at various places in the vicinity of London, according to the nature of the work. When the number of the students renders it desirable additional instruments are provided, so that all may have a fair share of practice.

Fee:—15s. Members, 17s. 6d. Non-Members

for each part of the course, including use of instruments and assistant, but exclusive of railway fares. If prepayment be made for the three parts together, the fees will be 42s. and 45s. respectively. Each student will require a Note Book (6d.); Field Book (6d.); Level Book (6d.); Universal Chain Scale and Offset (5s.), all of which can be obtained in the class.

The periods of meeting are approximately as follows:—Part I., January to March; Part II., February to March; Part III., March and April; but unless a student joins at the commencement he should make enquiry as to the later dates.

A Prize of £1 1s. will be given by the Governing Body of the College to the student who, having regularly attended the Lectures and Field Work of the current session, passes the best Examination. Certificates of three grades will also be awarded.

NOTE.—Students desiring to attend any of the following Supplementary Courses should send in their names by the 1st March at the latest, in order that the necessary arrangements may be made. The fees for these are paid direct to the Professor.

Theodolite Work.

Part I.—THEODOLITE WORK, ELEMENTARY. (Three Lectures and Two Field Lessons).

LECTURE 1.—Introduction—Principle of Theodolite—Distinction between Theodolite surveying and chain surveying—Angular measurement—Notes on angles—Unit of measurement—Sub-divisions—Protractors: circular, semi-circular, and rectangular—Construction of protractors—Scale of chords—Construction of scale of chords—To set off, or measure an angle, with a protractor or scale of chords—Terms used in connection with angles and triangles—Various useful properties of angles—Principle of Box sextant—Diagram of construction.

LECTURE 2.—Vernier scale—Enlarged working model—Explanation—Construction of theodolite—Setting up and adjusting—Taking magnetic bearing—Reverse bearing—Taking horizontal angles—Repeating the angle—Taking vertical angles—Surveying by the compass bearings—By the back angle—By two stations—Field notes of survey from two stations, including chain lines and offsets.

LECTURE 3.—Cases in which theodolite is required—Surveying by back angle—Example of survey of lake—Check upon angles of a closed traverse—Example of survey of road through forest—Check observation to a previous station—Example of survey of river—Calculation of areas.

FIELD LESSON 1.—Practical work in setting up and adjusting Theodolite—Setting up over given station—Taking bearing of base line—Reading angles.

FIELD LESSON 2.—Practice in surveying by back angle—Traversing with Theodolite.

Part II.—THEODOLITE WORK. TRIGONOMETRICAL.

Three Lectures and Two Field Lessons.

NOTE—*In this Course it is assumed that students have no previous knowledge of mathematics.*

LECTURE 1.—Determination and comparison of angular magnitudes—Meaning of term ratio—Definition of the sine of an angle—Trigonometrical functions and ratios—Assistance derived from mnemonics—Complement and supplement of an angle—Angles in the second quadrant—Examples.

LECTURE 2.—Construction of logarithms—Base, index and mantissa—Use of logarithmic tables—Multiplication, division, involution, evolution by logarithms—Table of natural sines and cosines—Table of tangents, &c.—Examples.

LECTURE 3.—Formulæ for heights and distances—On level and sloping ground—Accessible and inaccessible objects—Sketches shewing application—Examples.

FIELD LESSON 1.—Setting out base line on level ground—Observations to various distant church spires—Calculation of distances—Enlarging base—General triangulation work.

FIELD LESSON 2.—Setting out base line on sloping ground—Taking levels with Theodolite—Observations for height to top of Structure—Checking by second set of observations—Work to be plotted and calculated.

Fee—One Guinea for each part singly, or One-and-a-half Guineas together.

Engineering Field Work.

(Four Lectures and Two Field Lessons.)

LECTURE 1.—General route—Setting out on the straight—Ranging both ways—Instruments used—Permanent Stakes—Level pegs—Bench marks—Staking at embankments and cuttings—Bridge sites—Gradients—Batters and slopes—Formation breadths—Setting out side widths—Diagrams and formulæ—Working section book.

LECTURE 2.—Curves—Modes of designating radius—Angle of deflection—Nomenclature of curves—Computation of curves—Boundaries given, to find radius—Radius given to find boundaries—Curve formulæ and tables.

LECTURE 3.—Various systems of setting out curves—Ranging curves—Common method—By oblique offsets—By rectangular offsets—By angles of deflection with one theodolite.

LECTURE 4.—Setting out curves continued—By angles of deflection with two theodolites—By Baker's parabolic system—By the single chord system—Curves on bridges and viaducts—Compound curves—Crossings and turnouts—Super-elevation of outer rail.

FIELD LESSON 1.—Setting out on the straight—Staking out side widths on irregular ground.

FIELD LESSON 2.—Ranging curves with chain and theodolite on various systems.

Lectures and Field work, Fee: One Guinea.

Town Surveying.

Students for this course must be able to use a Theodolite and have a general knowledge of Chain Surveying.

(Two Lectures and one Field Lesson).

LECTURE I.—Distinction between Town Surveying and ordinary Land Surveying—Theodolite Traverse—Connection with surrounding triangulation—Base and tie lines—When angles may be omitted—Stations how marked—Chains and Tapes—Rectangular offsets—Oblique or triangulated offsets—Method of keeping field-book for chain lines—Field book for details—Order in plotting work—Hints on sketching and putting in measurements—Examples of lines and angles of Town Survey from field-book without the offsets—Example of one line with offsets and sketches.

LECTURE II.—Difference in laying out between ancient and modern towns—Causes of same—Ordnance town maps of various scales—Limit of accuracy determined by the scale adopted—Table of limits—Double chain lines—Example of same with sketches from field-book—Detail of back premises, how measured—Precautions to be adopted—Examples from field-book.

FIELD LESSON I.—Survey of streets with theodolite—Filling in details at same time.

Lectures and Field work, Fee, Half-a-Guinea.

Laying-out Building Estates.

LECTURE.—Locality as affecting value—Personal visit necessary—Class of property regulating size of plots—Examples of small estates—Alternative arrangement of plots—Frontages, roads and approaches—Rights of way—Reserved portions—Width of roads—Building line—Regulations within the Metropolitan area—Cost of land—Cost of laying out roads and footpaths, fencing, &c.—Price per plot—Ground rent—Proportion to rental value of house—Minimum value of buildings to be erected—Return for outlay—Special circumstances affecting developed value—Legal and Surveyor's charges—Specification for roads and drains—Agreement for Lease—Lease—Conveyance.

FIELD LESSON.—Staking out building plots—Use of cross staff—Taking levels with one line of collimation—Shifting station of instrument—Incidental work.

Lecture and Field work, Fee: Half-a-Guinea.

Compass Traversing.

(Two Lectures and One Field Lesson.

LECTURE I.—Magnetic and true meridians—Pocket compass—Variation of compass—Points of the compass—Various modes of marking the card—Prismatic compass, construction and use—Route surveys—Plotting by bearings—Check bearings—Plotting by distances and offsets, or latitude and departure—Consecutive co-ordinates—Independent co-ordinates—Examples.

LECTURE II.—Reduction of a traverse—Use of traverse tables—Use of trigonometrical tables—Field book—Form of record for reduction of traverse—Open traverse—Closed traverse—Examples.

FIELD LESSON I.—Practical work in the field in open or closed traverse.

Lectures and Field Work, Fee: Half-a-Guinea.

Other courses—as Contouring, Railway, Mine and Marine Surveying will be given whenever there are sufficient applicants.

NOTICES OF MEETINGS, PAPERS, &c.

From the leading Institutions and Societies are regularly posted in the Engineering Department of the College, and visits are made to Works in Progress during the Session in connection with various professional bodies. Particulars are announced in the Classes.

Reading Room.

All the leading Technical papers are now kept in the Reading Room of the College for the use of students.

Technical Library and Museum.

A valuable collection of technical works has been added to the Library, and is now available for circulation or reference. A technical museum is in course of formation, and gifts of illustrative objects in all branches are solicited.

Science Society.

The ordinary meetings are held on the last Wednesday in each month at 7 p.m. Subscription 2s. 6d. per annum. Papers on scientific subjects are read and discussed at the ordinary meetings, and excursions are made to Engineering Works and places of interest through the summer.

The following works by Prof. HENRY ADAMS will be forwarded free by Post on receipt of Postal Order to 60, Queen Victoria Street, E.C.

CLASS NOTES IN TECHNICAL DRAWING. Sixth edition, crown 8vo., 12 pp., with note book containing 96 pp. of squared paper, and pencil, 6d.

* * A capital form of note book for students. * * The notes are useful and have been suggested by a lengthened experience in teaching. The ruled pages, about 7 in. by 4½ in., divided into ¼ in. squares, are invaluable for sketching to scale. Every architectural and engineering student should get a copy. * *—*Building News.*

As may be inferred from the title, this book consists mainly of ruled paper for notes. The notes embody all information relating to instruments required, tables of colours for representing different materials, and each and every item which long experience have been able to suggest, in order to make attendance at lectures and classes a real comfort.—*Science and Art.*

This useful little *vade mecum* (intended primarily for students at the College) contains handy class notes, the syllabus of the City of London College (City Polytechnic), and a quantity of useful ruled paper for students' memoranda and class-notes.—*Illustrated Carpenter and Builder*

JOINTS IN WOODWORK. A Paper read before the Civil and Mechanical Engineers Society, containing information upon the varieties, properties, market sizes, &c., of timber, the principles of designing joints, the form and arrangement of joints and fastenings, proportions of bolts, strength of fastenings, &c. Third edition. Sixth thousand. Demy 8vo. 40 pp. with large plate of 30 joints, 1s.

* * The subject upon which the author treats is of so much importance to the joinery trade, that we think it well to draw the special attention of our readers to the paper. In it they will find a large amount of information, very clearly written, and easily understandable by means of a sheet of illustrations giving sketches of the various forms of joints, &c., mentioned in the paper.—*Builders' Weekly Reporter.*

Mr. Henry Adams has done good service not only to students, but to those who are in actual practice by the issue of the above handy little works, which form part of a series of handy books on technical work. The author is not only a civil engineer in full practice, but also attained high honours, and is teacher of mechanical engineering and building construction, &c., at the City of London College, and he possesses in an eminent degree the faculty of imparting his instructions in a clear and lucid manner. * * Of the little works before us the one on Joints in Woodwork is replete with solid information in a compact form, illustrated with a sheet of eighty-two diagrams of various forms of jointing. * *—*The Cabinet Makers' Guide.*

* * deals at some length upon the botanical characteristics of trees, the classification of timber, and its application mainly for carpentry and joinery. Special attention is given to the important subject of *joints*. The paper in replete with valuable information upon the structure and formation of beams, roofs, and miscellaneous joints used in carpentry and engineering works, which is still further exemplified by a plate of eighty drawings.—*The Illustrated Carpenter and Builder.*

* * is a work which will be serviceable to joiners and builders. The subject is treated in a thoroughly able style and extensively. * *—*Timber News.*

* * We commend this work, with its sketches and diagrams, to all who are interested in the building trades, since its information is of the greatest importance. Mr. Adams knows his subject, and deals with it in a practical manner that cannot fail to impress its facts upon the memory of the student.—*The Timber Trades' Journal.*

* * It is a useful work for joiners, builders and contractors, and also for apprentices. The large sheet of diagrams is very instructive. It shows not only how to make all manner of joints, but how to convert timber into boards from the log.—*Timber News.*

* * Professor Adams' paper treats in a thoroughly comprehensive manner this subject. He takes it out of the dry, technical phraseology of the treatise, and handles it from a philosophical standpoint. * * The paper may be read with advantage by all students of wood or timber construction.—*Building News.*

* * Will doubtless be appreciated by all practical engineers and architects. The subject is treated in a clear and masterly way, and is illustrated by numerous figures.—*Society of Architects Journal.*

This unpretentious little pamphlet is an excellent treatise on a subject rarely dealt with in so small a compass. * * The joints are well classified, and, as far as the paper goes, accurately described. Care is taken all through to explain the reason for the form of the joints, and there is one plate crowded with good drawings. We can commend this brochure as a thoughtful and well digested introduction to the serious study of this section of building construction.—*Technical World.*

* * The facts and methods given may be taken, of course, to be the best of their kind from such a recognised authority, and the booklet may serve as a handy book of reference to the manual instructor in any case of doubt.—*Schoolmaster.*

We have also received the same author's "Joints in Woodwork," and here again we can commend the clearness and the arrangement. * * and the book now before us lucidly clears away those difficulties, and shows us how wood may be lengthened and strengthened, or secured by udicious jointing.—*Surveyor.*

BUILDING CONSTRUCTION. A KEY TO THE EXAMINATIONS OF THE SCIENCE AND ART DEPARTMENT. Containing all the questions in the Elementary and Advanced Stages with their diagrams, and fully worked answers with drawings; classified under trades and grouped according to subject, complete for the thirteen years 1881-93, with copious index and cross references and over 300 illustrations. Crown 8vo. cloth gilt, xiv. + 243 pp., price 4s.

Colonel Seddon, R.E., the Examiner in this subject to the Science and Art Department, in acknowledging a copy of the book, says—"It has evidently been compiled with great care, and will be a valuable assistance both to Teachers and Students."

"Another useful textbook * * illustrated with many capital diagrams. The author has proceeded on the theory that a classified collection of the questions asked during the last thirteen years will be of great utility to competitors and to teachers."—*Daily Telegraph.*

"* * Students will look upon the book as a sort of store containing all the answers they are likely to need for the winning of prizes and honours. As there are 338 problems, examiners can hardly think of a subject that is not illustrated. Mr. Adams, it must be allowed, has done his model answering creditably, and he must be a dunce who cannot make himself with the help of the book so as to satisfy the kindly hand of Examiners. * *—*The Architect.*

"* * In view of the general fashion nowadays to test educational ability by examination papers, the publication of such a book is most opportune. * * The writer must know his subject thoroughly, *i.e.*, be intimately acquainted with all its ramifications; he must have taught the subject successfully, and he must be able to appreciate the examiners' idiosyncrasies. These qualifications are guaranteed in Mr. Adams; his recognised position in the mechanical world, and as an instructor for a long period at one of our well-known technical colleges, ensures all these qualifications. The student may feel without reserve that he is in good hands while he peruses this book. * *—*Science and Art.*

"* * This publication should be particularly useful to students preparing for the examination of the Science and Art Department. * * The author's extensive knowledge of the subject and his great experience as a teacher are admirable qualifications for the work, which appears to be exceedingly well done. Diagrams are all important in the study of building construction, and Mr. Adams leaves nothing to be desired in this respect. The arrangement is particularly good * * The book is evidently a good one, and is sure to be studied by students and others interested in the subject.—*Glasgow Herald.*

"Students must feel under great obligations to Mr. Henry Adams * * The diagrams are numerous, and these, coupled with the large amount of practical information, clearly stated, provide the student with the nearest approach to a royal road to success that he can have.—*Leeds Mercury.*

"The candidate who is going in for this examination will find Mr. Adams' book just what he wants * * and the book will be a useful work of reference to every architect and student, apart from its immediate educational value to candidates in the examinations of the Science and Art Department.—*Building News.*

"* * There is truth in the statement that there is no royal road to success in the examinations of the Science and Art Department. All candidates have, of course, to climb the difficult route by sheer hard work. * * Both prospective competitors and teachers will find this manual of service.—*The Speaker.*

"* * An aid to success in examinations in technical trade subjects is the mastering of questions which have puzzled candidates in previous years. Such is the line of teaching adopted in "Building Construction" by Henry Adams. * * Such a work cannot fail to be a valuable help to the ambitious student.—*The Star.*

"* * As a teacher of twenty-five years' experience, Mr. Adams may be expected to show lucidity and terseness in his solutions, qualities so essential to the high success of the candidate. Consequently we not only find a complete record, as it were, of the Science and Art Examinations in this subject for thirteen years, but we also have a *corpus* of information which must prove most useful as a ready help in preparation work as well as for reference. * *—*Journal of Society of Architects.*

"* * The series of technical handbooks for the student in engineering and architecture which have appeared under the name and seal of Professor Henry Adams amount almost to a small library, and entitle their author to the grateful remembrance of students and teachers alike. The latest addition to these valuable works is a key or guide to the Science and Art Department's examinations in building construction. * * But the usefulness of the book being by no means restricted to the examination student pure and simple, a thorough index is provided, to serve as a guide for the practising architect or practical builder who may find this work valuable for reference. As with all Mr. Adams' text-books, the work is everywhere thoroughly careful and well done. The answers are concise, the drawings accurate and clear, and in conformity with the general directions issued by the examiners. * *—*School Board Chronicle.*

"* * Mr. Adams' book goes rather further. It prepares the student for the South Kensington examinations, and the long experience of the writer has shown him how to do this in a thoroughly satisfactory manner. Mr. Adams is at once an expert and a clear expositor.—*Bradford Observer.*

"The great ability of the author of this work, in the direction of practical lucidity, and in the preparation of coaching text-books for examination purposes, is so well known that from the beginning we have no hesitation in pronouncing the treatise in question as amongst his happiest efforts. Mr. Adams has a unique power of making his subjects of palatable interest to his students without being superficial. His works

of the kind are always eminently intelligible and abounding with useful hints of guidance in the smallest consistent space. *,*—*Invention.*

The subject of building construction is here treated in a similar manner to that adopted by a skilful teacher of mathematics when he works out model problems for his pupils' imitation. * * As the outcome of twenty-five years' experience as a teacher of the subject, the volume is invaluable to all earnest students, and should meet with a large and ready sale. It is the useful and faithful handmaid to the recognised text books on building construction.—*Schoolmaster.*

A valuable work by one who is known to possess peculiar qualifications for imparting knowledge and high attainments in the branches he teaches. * * The book is a most useful one for architects, surveyors, and builders, and all students.—*Carpenter and Builder.*

* * Simply invaluable. * * Professor Adams has had twenty-five years' experience as a teacher. It is safe to add, therefore, that "Building Construction" will be as much appreciated by other teachers as by students.—*Surveyor.*

The author has been well-known by the publication of his answers to the questions given at the annual examinations for a good many years past. The more complete work now before us adds to his high reputation. * * "Building Construction" by Professor Adams should be in the hands of every student of Building Construction, and many who are not students but actively engaged in the various departments of building will find in its pages a mass of valuable information easily understood.—*Science and Art of Mining.*

This is a small but very useful book, as the manner in which it is laid out encourages the student to think for himself as to the methods and principles of construction, and the reasons for them. * * The name of the author is a guarantee as to the accuracy of the "answers."—*Builder.*

Those of our members who go in for South Kensington examinations will find this useful as a "cramming" book. * * Necessarily also it contains a good deal of useful information on construction.—*A.A. Notes.*

TIMBER PILING, in foundations and other works. A paper read before the Society of Architects in 1891. Second edition, demy 8vo., 24pp., with folded plate, price 1s.

* * In the course of his able paper the author treats his subject under the following heads:—1, the material; 2, its preparation; 3, pile-driving; 4, the supporting power of piles; 5, examples of the use of piling. The paper is illustrated by a folding plate of 34 diagrams, which are of great assistance to a proper understanding of the text.—*Steamship.*

* * We need scarcely add that in the hands of such an acknowledged authority the information suggested by these headings is forthcoming in clear, compact and accurate form. In fact, within the comparatively

limited compass of a 24-page pamphlet, Prof. Adams has managed to compress guiding principles that will be invaluable to the practical man. With the pamphlet is bound up a large folded plate of 34 illustrative diagrams. We are not surprised that this exhaustive little essay should already have run into a second edition.—*Surveyor.*

* * Should prove of value to all engaged in such works.—*Timber Trades Journal.*

* * Receives ample justice at Mr. Adams' hands. More than usually interesting.—*Timber.*

* * His eminently practical paper, with its illustrations, will be perused with interest by those of our readers who have to do with building piers and dams.—*Marine Engineer.*

So useful that a second edition has become necessary. We did not notice the paper at the time, and therefore take this opportunity of recommending all students of engineering construction to procure a copy of the reprint, and we can promise that whoever does so will have at command an exceedingly useful epitome of practical information on the object. All that Professor Adams does in this way he does thoroughly—not with any display of abstruse learning, but keeping in view the ordinary requirements of constructors.—*Journal of Gas Lighting.*

* * Contains so much that is of practical value, that a second edition in a handy form is especially welcome. * * Contractors for harbour and other public works should be particularly interested in Mr. Adams' carefully prepared and able paper.—*British Trade Journal.*

* * This is a reprint of a lecture delivered before the Society of Architects, and one which builders, contractors and others interested in piling will do well to read, as considerable instruction is to be gained from the 24 pages of matter and the folded plate, on which are some 34 diagrams. * * Each branch of the subject is fully illustrated on the sheet of diagrams.—*Timber Trades.*

THE STRENGTH OF IRON & STEEL.—A paper read before the City of London Lodge Science Society, 4th January, 1887, with tables of the ultimate and working loads under various conditions. Demy 8vo, 16 pp. and folding plate. 6d.

Contains in a concise form the leading facts connected with the results of testing iron and steel. Students will find this little book a useful introduction to other treatises.—*Building News.*

A very interesting and instructive paper * * we have pleasure in commending to our readers a perusal of its pages.—*Builders' Reporter and Engineering Times.*

* * Some exceedingly useful information * * treats simply and concisely of various methods of testing iron and steel. Tables are given showing the strength and safe working load for iron and steel, and the different modes of testing finished works, such as girders and bridges, are also described. Altogether Mr. Adams' little pamphlet forms a very useful compilation of elementary information on the subject of which it treats.—*British Architect.*

* * A well written and timely *brochure,* * * The charm and great value of Mr. Adams' teaching and lectures is in the clearness and simplicity of language; whilst the use of complex algebraical problems is avoided, so that these lectures can be readily understood by all classes of students, builders, and metal workers.—*Carpenter and Builder.*

STRAINS IN IRONWORK. A course of Eight Elementary Lectures delivered at the request of the Society of Engineers in their Hall in 1882-3. The subject is treated fully, without mathematics, and the examples include all the more common structures for which the stresses require to be determined. Crown 8vo, cloth, with 8 plates containing 172 illustrations, 5s. 0d.

This book has been widely adopted as an introductory text book to Graphic Statics and Structural Mechanics, and is now stereotyped.

* * For the task to which the Council invited him Mr. Adams is specially fitted. His thorough practical knowledge of every detail of the subject upon which he treated gave him unusual advantages, and the result has been that a more valuable work than the one before us could not be placed in the hands of the young beginner. In lectures of this character there is of necessity a good deal of technical language made use of, but Mr. Adams makes his meaning clear to the veriest tyro in the profession, and this it is which lends additional value to his very excellent work.—*Builder's Weekly Reporter.*

Such a book was required by engineers who had not mastered sufficient mathematics to understand formulæ found in more advanced treatises. * * In the last lectures the reciprocal diagram of forces, as introduced by Professor Clerk-Maxwell, is explained; and the author considers various applications of it to roof trusses, from the simple triangular roof to more complex forms such as Warren and lattice girders. These two lectures alone are worth the price of Mr. Adams' little book to the student, and will enable him to apply to iron and other structures a principle that must ultimately supplant the older and more laborious process of calculation. We are happy to recommend the book as exhibiting the practical application of formulæ to structures in a simple manner.—*Building News.*

* * Its great point of merit, and that in which it differs from most of the other text books, is that the calculations are based on simple proportion and the plainest of algebraical and arithmetical statements.

This is exactly what is wanted to meet the demand we referred to. Mr. Adams' long experience as a lecturer in the engineering department of the City of London College has enabled him, in our opinion, to place these dry and technical matters before his readers in a way suited to the capacity of the average student, so concisely as to leave a large increase of information with the reader without undue wearying of the attention by unnecessary details.—*Inventors' Record.*

Judging by the number of students who attended the lectures and the interest that was displayed throughout, an interest to which we can testify, the little volume now issued is sure to be welcomed by them, especially as it contains the diagrams shown during the delivery of the lectures.—*Iron.*

* * treats the subject in a very elementary though clear and concise manner—a method of treatment which will be found particularly useful to those who desire to obtain a knowledge of the subject, and possess but little mathematical skill. * * This work will be found a very useful and handy little book, containing a great amount of information in a small space, and yet entering into principles sufficiently to satisfy the student of the truth of the deductions, and thereby fix them in his memory; and those who attended the author's lectures as well as general readers, will do well to possess themselves of so handy and easy an introduction to graphic statics.—*The Builder.*

* * It is one of the clearest, if not the clearest, and most simple of handy books for learners, on strains in ironwork, as of roofs and girders, with which we have met, and although approximate methods are in a few cases employed, the book is exceedingly well adapted to enable students to understand with facility the more complete books and more complex problems dealt with in books which do not descend to the level of the uninstructed. No reader desirous of acquiring learning on this subject can fail to feel himself put well on the ladder by Mr. Adams' book.—*Engineer.*

* * The lectures, while explaining the scientific principles on which strains are calculated, are of a practical character, and consequently of daily utility to the professional man. They may be recommended to students and assistants.—*English Mechanic.*

This is a capital little book, and does not require a knowledge of arithmetic beyond simple proportion.—*Technical World.*

A useful little book, having the great advantage that unlike many other works it does not assume too high a degree of proficiency in mathematics in those who want to study the subject. * * The methods are clear, and without any difficulty a careful reader ought to be able to understand the rudiments at least of calculation, both by formulæ and graphic statics.—*A.A. Notes.*

WIND PRESSURE ON ROOFS. A paper read before the Society of Architects in 1890. Second edition, revised. 12pp. with folded plate, price 6d.

* * * The Society of Architects has of late been unusually fortunate in securing for its "Transactions" a series of papers of wide interest. One, on a subject as to which little information is available, was that contributed by Prof. Henry Adams, * * * which will form an acceptable complement to his pamphlet on "Designing Cast and Wrought Iron Structures."—*The Surveyor.*

THE FORCE OF THE WIND. A paper read before the Chemical Engineers' Section of the London College of Science in 1895. Demy 8vo and wrapper, with tables of velocity, pressure, and safe loads. Price 6d.

DESIGNING WROUGHT AND CAST IRON STRUCTURES. In five parts. Part I.—Wrought and Cast Iron Girders. Part II.—Wrought Iron Girder Bridge complete; part III.—(out of print); part IV.—Trussed Beam, Cast Iron Stanchion and Riveted Joints; part V.—Wrought Iron Roof Truss and Cast Iron Hollow Columns. For particulars of revised issue see next page. The remaining stock of these parts is now on sale at half price, and post free.

THE PRACTICAL DESIGNING OF STRUCTURAL IRON-WORK. First series demy 8vo, cloth, 200 pp., with 14 folded plates containing 180 diagrams. Price 8s. 6d.

This is a new edition of Designing Wrought and Cast Iron Structures which was issued in five parts, now brought into one volume, with corrections and many additional notes.

* * * A volume that will be welcomed by all engineering and architectural students. Of the merits of Professor Adams' method and treatment we have before spoken with commendation, and we believe that many a student has learnt more from these practical examples of designing than they have from the ordinary textbook of which there are so many, filled with algebraic formulæ and equations unintelligible to the majority of students. Any student who desires to acquaint himself with the subject of construction cannot do better than join the classes of Professor Adams.—*Building News.*

* * * A most useful work for engineers and architects.—*Glasgow Engineer.*

Engineers would find this volume a useful book for reference when they are actually engaged in designing ironwork.—*Iron and Coal Trades Review.*

Professor Adams' literary productions are eminently practical as well as educational, and the present work just issued under the above title fully deserves recognition on this ground. The text is accompanied by more than a dozen plates drawn to scale, rendering the work of designing this class of work a facile matter. Indeed, with the preliminary information as to stresses, which can be gathered by beginners from the author's book on "Strains in Ironwork," any business man with a clear head and possessed of a slight knowledge of engineering could, if necessary, prepare a design and reckon up the cost.—*Machinery Market.*

This is a truly admirable work. We do not remember to have met with a clearer, more concise and practical treatise on structural ironwork design. Not alone is the information eminently practical and to the point, devoid of irrelevant theory and useless padding, but the author's method of arranging it is the best possible way of conveying the instruction which is intended. We think that this method might with advantage be adopted by writers upon other technical and engineering topics.—*Electricism.*

A very distinct feature in this work is the almost entire absence of any unnecessary padding—in fact, the matter really consists of a series of numerical answers dealing with diverse cases, with brief notes, an excellent selection of illustrations being included. The book is certainly an attractive one.—*Electrical Review.*

Presents to the engineer and student a series of minutely worked-out designs for various kinds of ironwork. These include girder and wrought iron girders of various forms, rolled joists, roof trusses and special portions of structural ironwork. These designs are accompanied by practical remarks which enable the designer to apply them in the working out of any dimensions. Throughout the book there are many valuable observations about factors of safety, and the chapter on riveted work is well worth studying, as it is meant to prevent many mistakes often made by designers. * * The work is clearly and concisely written, and a knowledge of algebra or higher mathematics is not needed to understand and profit by the contents.—*Industries and Iron.*

The book will recommend itself to those commencing the study of ironwork, because it is written in a thoroughly practical manner, and as each division of the subject has a chapter to itself, it is not necessary to master the whole before any of its contents can be applied. It was not the aim of the author to produce a book dealing with difficult ironwork, but it will be found he has omitted but very little that is likely to be of general use in the office of an engineer or architect.—*Builder.*

The author of this able and useful work is so well known in engineering circles and in connection with other literary contributions of a similar character, that introductory comments are scarcely necessary;

indeed, the name of Mr. Adams is practically a guarantee for a sound and valuable treatise on subjects of the kind. * * The treatment throughout the volume is concise and lucid, whilst the various calculations are simply explained so as to be easily within the grasp of those possessed of an ordinary knowledge of mechanics and the formulæ involved. No unnecessary technical verbosity is used, and the simplest kind of mathematical terms and computations are only employed, it is, therefore, undoubtedly a work that should find a place in every engineer's drawing office.—*Inventor.*

The author's object is to provide former students of the City of London College, and engineers and architects everywhere, with the valuable material collected by him for use in his class. He succeeds in producing a clear and useful work, giving the cream of engineering practice.—*Colliery Guardian.*

* * The descriptions are brief but ample, and are supplemented by numerous illustrations, and throughout the explanations are clear and easily understood. The author not only has a perfect knowledge of the subject with which he deals, but he has the somewhat rare ability of expressing himself in a manner which the most elementary student cannot fail to understand. He has that happy clearness and calmness of expression which at once makes one feel sure of being able to master the problems which are to be solved.—*Surveyor.*

* * Should find a place on the shelves of every architect's library. Each chapter is a subject in itself, and the practical manner in which the designs and calculations are worked out will enable the student of iron and steel construction to apply his knowledge to very many cases in every day practice.—*A. A. Notes.*

* * The volume is illustrated with large diagrams, and is a practical textbook for the use of students who wish to thoroughly understand the subject.—*English Mechanic.*

* * Many formulæ are given, and the illustrations are both numerous and clear. The descriptions accompanying the calculations are brief, but ample enough to make the whole of the working clear and definite to anyone who has had the ordinary preliminary training in the principles of mechanics and theory of stresses. The book is very handy for reference while designing, and ought to find its way to the shelves of every engineer's and architect's library.—*Society of Architects Journal.*

* * All the necessary calculations for the design of these structures are clearly given and simply expressed, and the whole subject is treated in an eminently practical manner. The work is certainly one which should be in the hands of every draughtsman and student interested in the design of structural ironwork.—*Mechanical World.*

DESIGNING IRONWORK. Second series: Part I. Steel Box Girder: Containing notes, calculations, stress diagrams, and working drawings for a steel box girder of minimum dimensions to carry a dead load of 100 tons, uniformly distributed over an effective span of 50 feet. Price 1s. 6d.

Among students the name of Professor Henry Adams must be a household word, so numerous are his books for their guidance, and so assiduous have been his labours as a lecturer. We have now before us the first part of his book on "Designing Ironwork," which deals with the calculations and drawings necessary for a steel box girder. The system of instruction is admirably arranged, and he who wishes to know all about the theory of girder construction cannot do better than read what the author has to say.—*Surveyor.*

*** By way of preface Mr. Adams makes one or two very practical observations upon the right method of adopting and applying theoretical calculations in designing ironwork. * * *—*British Architect.*

* * We can fully recommend this book * * to all students and engineering draughtsmen.—*Building News.*

*** Mr. Adams is a thoroughly practical teacher, and he goes about his work in a thoroughly practical fashion. Evidence of this is to be found in the custom, which he has instituted, of placing in the hands of his students a carefully compiled brochure containing notes, calculations diagrams and drawings relating to the subject chosen for his lectures. * *—*Iron and Coal Trades Review.*

*** We recommend the little book as a model worthy of the attention of all who wish to be something more than "rule of thumb" experts.—*Science and Art.*

*** Everything that is necessary for the student to know to enable him to design a girder of this kind is clearly explained, and there would be no difficulty in constructing the work from the information on the drawing given by the author.—*Builder.*

*** A sound mathematical training is undoubtedly imperative if an engineer is to excel in structural design, but the author holds the opinion—which we have repeatedly expressed—that all calculations must be viewed in the light of practical experience, and it is this clear realisation on his part in connection with these various papers that makes them so exceedingly practical to all engineers interested in the subject.—*Practical Engineer.*

*** The design is characterised by the same care and thoroughness which distinguish the author in all his other works.—*Colliery Guardian.*

*** The series of which this forms part is intended to take the place of elaborately worked examples to be studied in connection with the use

of a standard treatise, and this includes the subject of motive power in an admirable manner. The information is put in a simple and handy form for reference in the drawing office or shop, and these examples will be welcomed by the student as a glimpse into the routine of a civil engineer's drawing office.—*Industries and Iron.*

* * Valuable notes. * * The information given is simply put, in a brief and handy form, for reference while the actual design is in progress. —*Carpenter and Builder.*

* * All calculations are clearly given and explained, and extremely valuable information in connection with the working out of the design arrived at, is also added. * * —*Architect.*

HYDRAULIC MACHINERY: PAST AND PRESENT. A Lecture delivered to the Railway Officials' Association in 1880; being a historical account of hydraulic appliances from the earliest times, and especially of those designed by Sir Wm. Armstrong for railway purposes. Second Edition. Demy 8vo., 42 pp., with plate of 31 illustrations, 1s.

* * Mr. Adams' lecture will be read with interest, as glancing at a very important development of engineering.—*The Building News.*

* * It is a very readable book, and the author deals with his subject, from its earliest stages up to the present time, in a very clear and concise manner.—*Mechanical Engineer.*

* * Full of interesting and sound information, copiously illustrated by diagrams.—*Cabinet Makers' Guide.*

HANDBOOK FOR MECHANICAL ENGINEERS. A condensed summary of facts and formulæ relating to the practice of Mechanical Engineering, with especial regard to the requirements of students preparing for the examinations in Mechanical Engineering, Machine Construction Honours, and Applied Mechanics. Fourth edition, with portrait and copious index, cloth, Crown 8vo., viii + 398 pp., price 7s. 6d.

* * After having looked through the greater part of the book carefully, we are glad to find that the comprehensive and useful collection of notes and formulæ which the book now presents is one which fully merits its acceptance as a necessary addition to the mechanical engineer's handy books of reference. * * The various notes are selected with a practical knowledge of an engineer's most frequent requirements, and it must be taken as equally useful to the student as giving facts and values relating to the actual problems, forming a practical antidote to the more or less useless puzzles put together as class and examination questions. * *—*The Engineer.*

* * Provides in a very condensed form, the cream of engineering literature. * * we believe most engineers will find it a most welcome addition to their bookshelves as containing, in a collected and condensed form, information that otherwise could, perhaps, only be obtained by laborious searching.—*Mechanical World.*

* * We do not know where students can find a work with which we can more cordially recommend them to begin. It is admirable from every point of view. To students it will be invaluable. Mr. Adams is a professor at University College, and we congratulate his students on their tutor. The book deals with all the fundamental principles of mechanics, statics and properties of materials, strength of materials and structures, pattern-making and moulding, forging, welding and riveting, workshop tools and general machinery, power transmission by belts, ropes, &c., friction, thermo-dynamics, steam boilers, the steam engine, hydraulic machinery, electrical engineering, and sundry notes and tables.—*Colliery Guardian.*

It is just such a book as we have often felt the want of—one that would give us information at a glance that we could absolutely depend upon for accuracy; that would show clearly whether any formula of opinion applied, and what the range of its application was; that, in a word, was practical and in accordance with the requirements of engineers trained in the modern methods. * * The present high pressure system of working demands in books of reference, for use in the office or workshop, that the information shall be concise, accurate, and instantly available, and these conditions the book before us seems to fulfil. There is scarcely any information the mechanical engineer is likely to want that is not contained in its pages.—*Practical Engineer.*

* * The volume contains a mine of information. The theoretical portion is not unduly burdened with complicated formulæ. Those used are simple, and easily used by those not well up in the higher mathematics. Mechanical engineers have to thank Prof. Adams for putting within their reach a most useful book, clearly and concisely written, nicely printed and well bound, and one that certainly ought to be much used by mechanical engineers and those of the allied professions.—*Nature.*

* * The ability and high standing of the author are a guarantee of the standard qualities of his writings, and the brief and lucid manner in which the facts and opinions are put before the readers is beyond all praise.—*Invention.*

* * The book differs from any other that we have had before us, partaking largely of the character of the pocket-book, but with just sufficient of an explanation with each formula to enable a busy man to grasp at once the application of the information given. * * Professor Adams is a recognised authority on engineering matters, and he has the happy faculty of putting before readers in a clear, concise form just the information they want. The book is one we welcome heartily, and recommend those who have not yet bought a copy to do so at once.—*Machinery Market.*

* * Clearness and conciseness are its characteristic features.—*Journal of Gas Lighting.*

This is a book which appeals to a wide circle of readers, and it is gratifying for us to be able to say, after careful examination of its contents, that the work has been got up in such a form as is likely to

ensure for it a ready sale among mechanical engineers. * * The great beauty of this work is the large amount of information which has been put into a comparatively limited space. * * As a work of reference this handbook will be found invaluable in the hands of the professional mechanic.—*Engineer and Iron Trades Gazette.*

A capital book for students, and one that cannot fail to be appreciated by all who have sufficient interest in mechanical engineering to read about it. Although the work is good from any point of view, it is most valuable as a class book. * * —*The Colliery Manager.*

* * The information he gives us is in as condensed a form as is compatible with accuracy, and he has succeeded in presenting a handbook which will have a wide sphere of usefulness.—*Iron.*

* * Altogether, the book is calculated to give considerable satisfaction, and is a decidedly useful addition to the long series of engineering works which have been published.—*Electrical Review.*

We have seldom seen a better work of the sort than this little handbook, which is entering on its second edition. * * The author has skilfully selected such tables, calculation and formulæ as are likely to be most useful. * * and has added, in the form of notes, just the sort of information that is constantly wanted.—*British Trade Journal.*

* * Specially written for those who require facts and opinions put before them as briefly as possible, and the information given will be found useful by those who are entering life as mechanical engineers.—*English Mechanic.*

* * This excellent collection of engineering notes is of considerable value. The book is in many respects of the Meiklem orth type, though it contains more descriptive matter, and the usual tedious tables of circles, logarithms, &c., are conspicuous by their absence. The authorities for the various formulæ are given in most cases. We may add that a feature in the book is the excellent style in which the matter is printed, a characteristic of all Messrs. Spon's publications.—*Electrical Review* (second notice).

* * The work is, of course, largely a compilation, but the names of the sources from which it is extracted are always given, and these seem to have been selected with great care. All the ordinary branches of mechanical engineering are fairly well covered, and a copious index of subjects makes the contents easily available for reference. We have much pleasure in commending it.—*Industries.*

* * It contains a large amount of valuable information condensed into a small space and is written in the author's well-known concise and able manner. It is evidently the work of a master hand, and we heartily recommend it to the profession as an excellent book of reference.—*Invention* (Second notice).

* * Students of mechanical engineering will find in this book a mass of useful information in a condensed form. The rules and tables have been compiled from the best sources and are placed before the reader in a brief and convenient form. * * It forms a first rate handbook for young engineers, and is eminently adapted for that purpose.—*Steamship.*

Since the appearance of the first edition this work has stood in the front rank of the large and ever increasing array of engineers' hand books. The notes and formulæ are such as the engineer constantly has to refer to, and although primarily intended for the use of students, we venture to think that its chief sphere of usefulness will be in the engineer's works and drawing office.—*Science and Art.*

MACHINE CONSTRUCTION, ELEMENTARY. A key to the Examinations of the Science and Art Department. Containing all the questions set in the elementary stage with their diagrams, and fully worked answers with drawings, grouped according to subject, complete for the thirteen years 1881-93, with copious index. Crown 8vo., cloth, 116pp., 2s. 6d.

* * It is neatly got up, sketches are clearly drawn, whilst the answers to the questions given may be taken as a sample by students of the sentences it is desirable to adopt in connection with examination papers in this particular subject.—*Practical Engineer.*

* * If anyone feels the need of a key to help him in the final stages of preparation for this examination, he will probably derive some benefit from the excellently drawn solutions prepared by Mr. Adams.—*Glasgow Herald.*

The examples in this easy road to the machine construction and drawing examinations of the Science and Art Department are well chosen, and a youth learning from them will at the same time learn something of practical proportions.—*The Engineer.*

* * We should certainly advise elementary students to go carefully through this work. * *—*Mechanical World.*

Will be found very useful in many ways.—*English Mechanic.*

The work has been well done, the drawings are good and are all of practical utility, and the book, for the purpose of teaching drawing and giving the student a sound knowledge of the details of machinery, leaves nothing to be desired.—*The Builder.*

MACHINE CONSTRUCTION, ADVANCED. A key to the examinations of the Science and Art Department. Containing all the questions set in the advanced stage with their diagrams, and fully worked answers with drawings, grouped according to subject, complete for the thirteen years 1881-93, with index, 72 pp., and 17 folded plates. Crown 8vo., cloth, 2s. 6d.

* * The questions are all worked out with answers and suitable illustrations, and the book cannot but prove of use to students of engineering who have to go through examinations conducted on the same lines.—*The Scotsman.*

* * The qualifications for providing a key of this character will be admitted when it is stated that the author is Professor of Engineering at the City of London College, and that he has been assisted in respect of the solutions for the years 1892–3 by Mr. A. J. Lineham, of the Goldsmith Company's Institute, New Cross.—*Daily Telegraph.*

* * The subject, however, in view of the searching character of the questions that have been set by the examiners during the last dozen years, is not one that lends itself to the crammer, no matter how agile; and a careful study of the questions that have been set during this period, and which are here collected for ready reference along with intelligent answers, is itself equivalent to a course of training in the subject of machine construction, and to those interested in this particular subject the book will no doubt prove very useful.—*Practical Engineer.*

* * And, like other books issued by the author, is admirably adapted to its purpose.—*English Mechanic.*

Although there has been considerable improvement in the examining arrangements of the Science and Art Department, especially as regards the setting of suitable questions, still there is, in the machine construction and drawing, room for improvement. * * This is a matter which should receive serious consideration, as, naturally, there is not a fair all-round test of the various candidates' capabilities. In the meantime, such a work as that at present under review is helpful.—*Engineer's Gazette.*

One of the most useful books on machine construction and drawing we have seen for some time.—*Liverpool Post.*

* * The teacher of the advanced stage of machine construction will miss much if he fails to provide himself with this book, and to the pupil it is simply indispensable.—*Industries and Iron.*

appealing to and supplying the wants of students, and in this particular instance has excelled himself. Every elementary candidate in machine construction and drawing should get the Elementary volume, and every advanced student should get the Advanced volume. We tender to Mr. Adams and his publishers, Messrs. Chapman & Hall, our congratulations and our thanks.—*Science and Art of Mining.*

PRACTICAL TRIGONOMETRY: For Engineers, Architects and Surveyors. Section I., Angular Measurement. Section II., Principles of Trigonometry. Section III., Construction and use of Logarithms. Section IV., Trigonometrical Formulæ. Section V., Practical examples. Crown 8vo., cloth, 72 pp. illustrated., 2s. 6d. net, postage.

* * Is just what is wanted by young students. * * Professor Adam has the gift of being able to put into popular language much that many other people leave incomprehensible. * *—*Building News.*

* * Will be found useful by practical men, in enabling them to undertake the perusal of other than elementary works where a knowledge of trigonometry is essential. The book is so arranged as to graduall disperse the difficulties to beginners in Trigonometry, and it cannot but prove an incentive to urther study.—*Nature.*

This is likely to prove a very useful book, especially to young surveyors, in guiding their first timid steps in the mystery of Trigonometry. The usefulness and indispensability of the subject is shown by a few well chosen practical applications worked out completely. * * The definitions are given in a more interesting manner than will be found in the ordinary school books. * *—*The Engineer.*

We are often asked to recommend a good, intelligible and practical book on Trigonometry, at a reasonable price. We have now pleasure in doing so; "Practical Trigonometry" by Adams is very good, very intelligible, very practical, and very cheap. * * The intention of the author has been well fulfilled, and he has given us an admirable little book.—*Science and Art of Mining.*

* * Such a small book is very useful to those who require only the application of Trigonometry to the ordinary problems of surveying; the author's name is a sufficient guarantee as to its being reliable. * * His exposition of the subject is clear and simple.—*The Builder.*

THE BEHAVIOUR OF MATERIALS UNDER STRAIN. Demy 8vo., 4pp., 2d.

THE FORCE OF HAMMERS; OR, PERCUSSION v. PRESSURE. Demy 8vo., 6pp., 2d.

The following are now out of print.

USE AND CARE OF CHAINS, for lifting and hauling. A paper read before the Civil and Mechanical Engineers' Society in 1887. Royal 8vo., illustrated, 8pp., 1s.

APPARATUS FOR WEIGHING. Notes of a Lecture delivered to the City of London College Science Society in 1889. Demy 8vo., 8pp., 6d.

CIVIL AND MECHANICAL ENGINEERS' SOCIETY. Opening Address as President for Session 1889-90. Royal 8vo., 10pp.

SOCIETY OF ENGINEERS. Inaugural Address as President for 1890. Demy 8vo., 36pp.

CITY OF LONDON COLLEGE SCIENCE SOCIETY. Opening Address, with List of Officers and Rules. Demy 8vo., 8pp., 2d.

F. W. POTTER & CO., LTD., PRINTERS, ETC., 11, WORSHIP STREET, OLD BROAD STREET, E.C.

BOOKS RELATING TO APPLIED SCIENCE

PUBLISHED BY

E. & F. N. SPON, LTD.

LONDON: 125 STRAND.

NEW YORK: SPON & CHAMBERLAIN.

Algebra.—*Algebra Self-Taught.* By W. P. HIGGS, M.A., D.Sc., LL.D., Assoc. Inst. C.E., Author of 'A Handbook of the Differential Calculus,' etc. Second edition, crown 8vo, cloth, *2s. 6d.*

CONTENTS:

Symbols and the Signs of Operation—The Equation and the Unknown Quantity—Positive and Negative Quantities—Multiplication—Involution—Exponents—Negative Exponents—Roots, and the Use of Exponents as Logarithms—Logarithms—Tables of Logarithms and Proportionate Parts—Transformation of System of Logarithms—Common Uses of Common Logarithms—Compound Multiplication and the Binomial Theorem—Division, Fractions, and Ratio—Continued Proportion—The Series and the Summation of the Series—Limit of Series—Square and Cube Roots—Equations—List of Formulæ, etc.

Architects' Handbook.—*A Handbook of Formulæ, Tables and Memoranda, for Architectural Surveyors and others engaged in Building.* By J. T. HURST, C.E. Fifteenth edition, revised and enlarged, royal 32mo, roan, *5s.*

"It is no disparagement to the many excellent publications we refer to, to say that in our opinion this little pocket-book of Hurst's is the very best of them all, without any exception. It would be useless to attempt a recapitulation of the contents, for it appears to contain almost *everything* that anyone connected with building could require, and, best of all, made up in a compact form for carrying in the pocket, measuring only 5 in. by 3 in., and about ¾ in. thick, in a limp cover. We congratulate the author on the success of his laborious and practically compiled little book, which has received unqualified and deserved praise from every professional person to whom we have shown it."—*The Dublin Builder.*

Architecture.—*The Seven Periods of English Architecture*, defined and illustrated. By EDMUND SHARPE, M.A., Architect. 20 *steel engravings and* 7 *woodcuts*, third edition, royal 8vo, cloth, *12s. 6d.*

Baths.—*The Turkish Bath:* its Design and Construction for Public and Commercial Purposes. By R. O. ALLSOP, Architect. *With plans and sections*, 8vo, cloth, 6*s.*

Baths and Wash Houses.—*Public Baths and Wash Houses.* By ROBERT OWEN ALLSOP, Architect, Author of 'The Turkish Bath,' &c. *With cuts and folding plates*, demy 8vo, cloth, 6*s.*

Belting.—*Belt Driving.* By GEORGE HALLIDAY, Whitworth Scholar. *With plates*, 8vo, cloth, 3*s.* 6*d.*

CONTENTS:

Description of different Kinds of Belts—Pressure transmitted by Belts—Length of Belt and Coned Pulleys—Stretching of Belts—V Pulleys—Arms of Pulleys—Methods of Use of the Belt discussed—Rope Gearing—Tables—Rules for finding the Pitch of Spur-Wheels.

Blasting.—*Rock Blasting:* a Practical Treatise on the means employed in Blasting Rocks for Industrial Purposes. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. *With* 56 *illustrations and* 12 *plates*, 8vo, cloth, 5*s.*

Boilers.—*A Pocket-Book for Boiler Makers and Steam Users*, comprising a variety of useful information for Employer and Workman, Government Inspectors, Board of Trade Surveyors, Engineers in charge of Works and Slips, Foremen of Manufactories, and the general Steam-using Public. By MAURICE JOHN SEXTON. Fourth edition, enlarged, royal 32mo, roan, gilt edges, 5*s.*

Boilers.—*The Boiler-Maker's & Iron Ship-Builder's Companion*, comprising a series of original and carefully calculated tables, of the utmost utility to persons interested in the iron trades. By JAMES FODEN, author of 'Mechanical Tables,' etc. Second edition, revised, *with illustrations*, crown 8vo, cloth, 5*s.*

Brass Founding.—*The Practical Brass and Iron-Founder's Guide*, a Treatise on the Art of Brass Founding, Moulding, the Metals and their Alloys, etc. By JAMES LARKIN. New edition, revised and greatly enlarged, crown 8vo, cloth, 10*s.* 6*d.* net.

Breweries.—*Breweries and Maltings:* their Arrangement, Construction, Machinery, and Plant. By G. SCAMELL, F.R.I.B.A. Second edition, revised, enlarged, and partly rewritten. By F. COLYER, M.I.C.E., M.I.M.E. *With* 20 *plates*, 8vo, cloth, 12*s.* 6*d.*

Bridges.—*Elementary Theory and Calculation of Iron Bridges and Roofs.* By AUGUST RITTER, Ph.D., Professor at the Polytechnic School at Aix-la-Chapelle. Translated from the third German edition, by H. R. SANKEY, Capt. R.E. *With* 500 *illustrations*, 8vo, cloth, 15*s.*

Bridges. — *Plate Girder Railway Bridges.* By MAURICE FITZMAURICE, B.A., B.E., Mem. Inst. C.E. *Plates*, 8vo, cloth. 6*s.*

CONTENTS:

Formulæ and Tables of Loads and Weights for Plate Girder Bridges, with Remarks on the allowable Working Stresses to be adopted in Steel and Iron—The Market sizes of Plates and Bars, and the different kinds of Bridge floors, with examples worked out in detail.

Bridges.—*Stresses in Girder and Roof Trusses for both Dead and Live Loads by Simple Multiplication*, with Stress Constants for 100 cases, for the use of Civil and Mechanical Engineers, Architects and Draughtsmen. By F. R. JOHNSON, Assoc. M. Inst. C.E. Part 1, Girders. Part 2, Roofs. In 1 vol., crown 8vo, cloth, 6*s.*

Builders' Price Book.—*Spons' Architects' and Builders' Price Book, with useful Memoranda.* By W. YOUNG. Crown 8vo, cloth, red edges, 3*s.* 6*d.* *Published annually.*

Building.—*The Clerk of Works:* a Vade-Mecum for all engaged in the Superintendence of Building Operations. By G. G. HOSKINS, F.R.I.B.A. Sixth edition, fcap. 8vo, cloth, 1*s.* 6*d.*

Building.—*The Builder's Clerk:* a Guide to the Management of a Builder's Business. By THOMAS BALES. Fcap. 8vo, cloth. 1*s.* 6*d.*

Calculus.—*An Elementary Treatise on the Calculus for Engineering Students*, with numerous Examples and Problems worked out. By JOHN GRAHAM, B.A., B.E., Demonstrator and Instructor in Mathematics in the City and Guilds of London Technical College Finsbury. Crown 8vo, cloth, 7*s.* 6*d.*

Canals. — *Waterways and Water Transport in Different Countries.* With a description of the Panama, Suez, Manchester, Nicaraguan, and other Canals. By J. STEPHEN JEANS, Author of 'England's Supremacy,' 'Railway Problems,' &c. *Numerous illustrations*, 8vo, cloth, 14*s.*

Carpentry.—*The Elementary Principles of Carpentry.* By THOMAS TREDGOLD. Revised from the original edition, and partly re-written, by JOHN THOMAS HURST. Contained in 517 pages of letterpress, and *illustrated with* 48 *plates and* 150 *wood engravings.* Sixth edition, reprinted from the third, crown 8vo, cloth, 12*s.* 6*d.*

Section I. On the Equality and Distribution of Forces—Section II. Resistance of Timber—Section III. Construction of Floors—Section IV. Construction of Roofs—Section V. Construction of Domes and Cupolas—Section VI. Construction of Partitions—Section VII. Scaffolds, Staging, and Gantries—Section VIII. Construction of Centres for Bridges—Section IX. Coffer-dams, Shoring, and Strutting—Section X. Wooden Bridges and Viaducts—Section XI. Joints, Straps, and other Fastenings—Section XII. Timber.

Cast Iron.—*The Metallurgy of Cast Iron*: A Complete Exposition of the Processes Involved in its Treatment, Chemically and Physically, from the Blast Furnace to the Testing Machine. *Illustrated.* By THOMAS D. WEST, M. Am. Soc. M.E Crown 8vo, cloth, 12*s.* 6*d.*

Chemistry.—*Practical Work in Organic Chemistry.* By F. W. STREATFEILD, F.I.C., etc., Demonstrator of Chemistry at the City and Guilds Technical College, Finsbury. With a Prefatory Notice by Professor R. MELDOLA, F.R.S., F.I.C. Crown 8vo, cloth, 3*s.*

Chemists' Pocket Book.—*A Pocket-Book for Chemists, Chemical Manufacturers, Metallurgists, Dyers, Distillers, Brewers, Sugar Refiners, Photographers, Students, etc., etc.* By THOMAS BAYLEY, Assoc. R.C. Sc. Ireland. Fifth edition, 481 pp., royal 32mo, roan, gilt edges, 5*s.*

SYNOPSIS OF CONTENTS:

Atomic Weights and Factors—Useful Data—Chemical Calculations—Rules for Indirect Analysis—Weights and Measures—Thermometers and Barometers—Chemical Physics—Boiling Points, etc.—Solubility of Substances—Methods of Obtaining Specific Gravity—Conversion of Hydrometers—Strength of Solutions by Specific Gravity—Analysis—Gas Analysis—Water Analysis—Qualitative Analysis and Reactions—Volumetric Analysis—Manipulation—Mineralogy—Assaying—Alcohol—Beer—Sugar—Miscellaneous Technological matter relating to Potash, Soda, Sulphuric Acid, Chlorine, Tar Products, Petroleum, Milk, Tallow, Photography, Prices, Wages, Appendix, etc., etc.

Coffee Cultivation.—*Coffee: its Culture and Commerce in all Countries.* Edited by C. G. WARNFORD LOCK, F.L.S. Crown 8vo, cloth, 12*s.* 6*d.*

Concrete.—*Notes on Concrete and Works in Concrete;* especially written to assist those engaged upon Public Works. By JOHN NEWMAN, Assoc. Mem. Inst. C.E. Second edition, revised and enlarged, crown 8vo, cloth, 6*s.*

Coppersmithing.—*Art of Coppersmithing*: a Practical Treatise on Working Sheet Copper into all Forms. By JOHN FULLER, Sen. *Numerous engravings*, illustrating almost every branch of the Art. Royal 8vo, cloth, 12*s.* 6*d.*

Corrosion.—*Metallic Structures: Corrosion and Fouling, and their Prevention;* a Practical Aid-Book to the safety of works in Iron and Steel, and of Ships; and to the selection of Paints for them. By JOHN NEWMAN, Assoc. M. Inst. C.E. Crown 8vo, cloth, 9*s.*

Depreciation of Factories.—*The Depreciation of Factories and their Valuation.* By EWING MATHESON, Mem. Inst. C.E. Second edition, revised, with an Introduction by W. C. JACKSON. 8vo, cloth, 7*s.* 6*d.*

Drainage.—*The Drainage of Fens and Low Lands by Gravitation and Steam Power.* By W. H. WHEELER, M. Inst. C.E. *With plates*, 8vo, cloth, 12*s.* 6*d.*

Drawing,—*Hints on Architectural Draughtsmanship.* By G. W. TUXFORD HALLATT. Fcap. 8vo, cloth, 1*s.* 6*d.*

Drawing.—*The Draughtsman's Handbook of Plan and Map Drawing;* including instructions for the preparation of Engineering, Architectural, and Mechanical Drawings. *With numerous illustrations in the text, and* 33 *plates* (15 *printed in colours*). By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. 4to, cloth, 9*s.*

Drawing Instruments.—*A Descriptive Treatise on Mathematical Drawing Instruments:* their construction, uses, qualities, selection, preservation, and suggestions for improvements, with hints upon Drawing and Colouring. By W. F. STANLEY, M.R.I. Sixth edition, *with numerous illustrations*, crown 8vo, cloth, 5*s.*

Dynamo.—*Dynamo-Tenders' Hand-Book.* By F. B. BADT. *With* 70 *illustrations.* Third edition, 18mo, cloth, 4*s.* 6*d.*

Dynamo-Electric Machinery.—*Dynamo-Electric Machinery:* a Text-Book for Students of Electro-Technology. By SILVANUS P. THOMPSON, B.A., D.Sc. *With* 520 *illustrations.* Fifth edition, 8vo, cloth, 24*s.*

Earthwork Slips.—*Earthwork Slips and Subsidences upon Public Works:* Their Causes, Prevention and Reparation. Especially written to assist those engaged in the Construction or Maintenance of Railways, Docks, Canals, Waterworks, River Banks, Reclamation Embankments, Drainage Works, &c., &c. By JOHN NEWMAN, Assoc. Mem. Inst. C.E., Author of 'Notes on Concrete,' &c. Crown 8vo, cloth, 7*s.* 6*d.*

Electric Lighting.—*Electric Lighting: a Practical Exposition of the Art,* for the use of Engineers, Students, and others interested in the Installation and Operation of Electrical Plant. Vol. I. The Generating Plant. By FRANCIS B. CROCKER, E.M., Ph.D., Professor of Electrical Engineering in Columbia University, New York. *With* 152 *illustrations.* 8vo. cloth, 12*s.* 6*d.*

Electric Bells.—*Electric Bell Construction:* a treatise on the construction of Electric Bells, Indicators, and similar apparatus. By F. C. ALLSOP, Author of 'Practical Electric Bell Fitting.' *With* 177 *illustrations drawn to scale*, crown 8vo, cloth, 3*s.* 6*d.*

Electric Bells.—*A Practical Treatise on the fitting up and maintenance of Electric Bells and all the necessary apparatus.* By F. C. ALLSOP, Author of 'Telephones, their Construction and Fitting.' Sixth edition, revised. *With* 180 *illustrations*, crown 8vo, cloth, 3*s.* 6*d.*

Electric Currents.—*Polyphase Electric Currents and Alternate Current Motors.* By SILVANUS P. THOMPSON, B.A., D.Sc., M. Inst. E.E., F.R.S. *With* 171 *illustrations.*, demy 8vo, cloth, 12*s.* 6*d.*

Electric Telegraph. — *Telegraphic Connections*, embracing recent methods in Quadruplex Telegraphy. By CHARLES THOM and WILLIS H. JONES. *With illustrations.* Oblong 8vo, cloth, 7*s.* 6*d.*

Electric Testing.—*A Guide for the Electric Testing of Telegraph Cables.* By Col. V. HOSKIÆR, Royal Danish Engineers. Third edition, crown 8vo, cloth, 4*s.* 6*d.*

Electric Toys.—*Electric Toys.* Electric Toy-Making, Dynamo Building and Electric Motor Construction for Amateurs. By T. O'CONOR SLOANE, Ph.D. *With cuts*, crown 8vo, cloth, 4*s.* 6*d.*

Electrical Notes.—*Practical Electrical Notes and Definitions for the use of Engineering Students and Practical Men.* By W. PERREN MAYCOCK, Assoc. M. Inst. E.E., Instructor in Electrical Engineering at the Pitlake Institute, Croydon, together with the Rules and Regulations to be observed in Electrical Installation Work. Second edition. Royal 32mo, cloth, red edges, 2*s.*

Electrical Tables.—*Electrical Tables and Memoranda.* By SILVANUS P. THOMPSON, D.Sc., B.A., F.R.S., and EUSTACE THOMAS. In waistcoat-pocket size (2½ in. by 1⅝ in.), French morocco, gilt edges, *with numerous illustrations*, 1*s.*

Electricity. — *The Arithmetic of Electricity;* Manual of Electrical Calculations by Arithmetical Methods. By T. O'CONOR SLOANE, Ph.D. Crown 8vo, cloth, 4*s.* 6*d.*

Electrical Testing.—*A Practical Guide to the Testing of Insulated Wires and Cables.* By HERBERT LAWS WEBB, Member of the American Institute of Electrical Engineers, and of the Institution of Electrical Engineers, London. Crown 8vo, cloth, 4*s.* 6*d.*

Electrical Testing.—*A Handbook of Electrical Testing.* By H. R. KEMPE, M.I.E.E. Fourth edition, revised and enlarged, 8vo, cloth, 18*s.*

Electricity.—*Electricity, its Theory, Sources, and Applications.* By JOHN T. SPRAGUE, M. Inst. E.E. Third edition, thoroughly revised and extended, *with numerous illustrations and tables*, crown 8vo, cloth, 15*s.*

Electricity in the House.—*Domestic Electricity for Amateurs.* Translated from the French of E. HOSPITALIER, Editor of 'L'Electricien,' by C. J. WHARTON, M. Inst. E.E. *Numerous illustrations.* Demy 8vo, cloth, 6*s.*

CONTENTS:

1. Production of the Electric Current—2. Electric Bells—3. Automatic Alarms—4. Domestic Telephones—5. Electric Clocks—6. Electric Lighters—7. Domestic Electric Lighting—8. Domestic Application of the Electric Light—9. Electric Motors—10. Electrical Locomotion—11. Electrotyping, Plating, and Gilding—12. Electric Recreations—13. Various applications—Workshop of the Electrician.

Electricity on Railways.—*The Application of Electricity to Railway Working.* By W. E. LANGDON, M. Inst. E.E., Superintendent Electrical Department, Midland Railway. *With* 142 *illustrations.* 8vo, cloth, 10*s.* 6*d.*

Electro-Magnet.—*The Electro-Magnet and Electro-magnetic Mechanism.* By SILVANUS P. THOMPSON, D.Sc., F.R.S. *With* 213 *illustrations.* Second edition, 8vo, cloth, 15*s.*

Electro-Motors.—*Notes on Design of Small Dynamo.* By GEO. HALLIDAY, Whitworth Scholar, Professor of Engineering at the Hartley Institute, Southampton. *Plates*, 8vo, cloth, 2*s.* 6*d.*

Electro-Motors.—*The Practical Management of Dynamos and Motors.* By FRANCIS B. CROCKER, Professor of Electrical Engineering, Columbia College, New York, and SCHUYLER S. WHEELER, D.Sc. *Cuts*, crown 8vo, cloth, 4*s.* 6*d.*

Engineering Drawing. — *Practical Geometry, Perspective and Engineering Drawing;* a Course of Descriptive Geometry adapted to the Requirements of the Engineering Draughtsman, including the determination of cast shadows and Isometric Projection, each chapter being followed by numerous examples; to which are added rules for Shading, Shade-lining, etc., together with practical instructions as to the Lining, Colouring, Printing, and general treatment of Engineering Drawings, with a chapter on drawing Instruments. By GEORGE S. CLARKE, Capt. R.E. Second edition, *with* 21 *plates.* 2 vols., cloth, 10*s.* 6*d.*

Engineers' Tables.—*A Pocket-Book of Useful Formulæ and Memoranda for Civil and Mechanical Engineers.* By Sir GUILFORD L. MOLESWORTH, Mem. Inst. C.E., and R. B. MOLESWORTH. *With numerous illustrations*, 782 pp. Twenty-third edition, 32mo, roan, 6*s*.

SYNOPSIS OF CONTENTS:

Surveying, Levelling, etc.—Strength and Weight of Materials—Earthwork, Brickwork, Masonry, Arches, etc.—Struts, Columns, Beams, and Trusses—Flooring, Roofing, and Roof Trusses—Girders, Bridges, etc.—Railways and Roads—Hydraulic Formulæ—Canals, Sewers, Waterworks, Docks—Irrigation and Breakwaters—Gas, Ventilation, and Warming—Heat, Light, Colour, and Sound—Gravity: Centres, Forces, and Powers—Millwork, Teeth of Wheels, Shafting, etc.—Workshop Recipes—Sundry Machinery—Animal Power—Steam and the Steam Engine—Water-power, Water-wheels, Turbines, etc.—Wind and Windmills—Steam Navigation, Ship Building, Tonnage, etc.—Gunnery, Projectiles, etc.—Weights, Measures, and Money—Trigonometry, Conic Sections, and Curves—Telegraphy—Mensuration—Tables of Areas and Circumference, and Arcs of Circles—Logarithms, Square and Cube Roots, Powers—Reciprocals, etc.—Useful Numbers—Differential and Integral Calculus—Algebraic Signs—Telegraphic Construction and Formulæ

Engineers' Tables.—*Spons' Tables and Memoranda for Engineers.* By J. T. HURST, C.E. Twelfth edition, revised and considerably enlarged, in waistcoat-pocket size (2¾ in. by 2 in.), roan, gilt edges, 1*s*.

Experimental Science.—*Experimental Science:* Elementary, Practical, and Experimental Physics. By GEO. M. HOPKINS. *Illustrated by* 890 *engravings*. 840 pp., 8vo, cloth, 16*s*.

Factories.—*Our Factories, Workshops, and Warehouses:* their Sanitary and Fire-Resisting Arrangements. By B. H. THWAITE, Assoc. Mem. Inst. C.E. *With* 183 *wood engravings*, crown 8vo, cloth, 9*s*.

Fermentation.—*Practical Studies in Fermentation*, being contributions to the Life History of Micro-Organisms. By EMIL CH. HANSEN, Ph.D. Translated by ALEX. K. MILLER, Ph.D., Manchester, and revised by the Author. *With numerous illustrations*, 8vo, cloth, 12*s*. 6*d*.

Foundations.—*Notes on Cylinder Bridge Piers and the Well System of Foundations.* By JOHN NEWMAN, Assoc. M. Inst. C.E., 8vo, cloth, 6*s*.

Founding.—*A Practical Treatise on Casting and Founding*, including descriptions of the modern machinery employed in the art. By N. E. SPRETSON, Engineer. Fifth edition, with 82 *plates* drawn to scale, 412 pp., demy 8vo, cloth, 18*s*.

French Polishing. — *The French-Polisher's Manual.* By a French-Polisher; containing Timber Staining, Washing, Matching, Improving, Painting, Imitations, Directions for Staining, Sizing, Embodying, Smoothing, Spirit Varnishing, French-Polishing, Directions for Repolishing. Third edition, royal 32mo, sewed, 6*d*.

Furnaces.—*Practical Hints on the Working and Construction of Regenerator Furnaces*, being an Explanatory Treatise on the System of Gaseous Firing applicable to Retort Settings in Gas Works. By MAURICE GRAHAM, Assoc. Mem. Inst. C.E. *Cuts*, 8vo, cloth, 3*s*.

Gas Analysis.—*The Gas Engineers' Laboratory Handbook.* By JOHN HORNBY, F.I.C., Honours Medallist in Gas Manipulation, City and Guilds of London Institute. *Numerous illustrations*, crown 8vo, cloth, 6*s*.

CONTENTS:

The Balance—Weights and Weighing—Sampling—Mechanical Division—Drying and Desiccation—Solution and Evaporation—Precipitation—Filtration and Treatment of Precipitates—Simple Gravimetric Estimations—Volumetric Analyses—Special Analyses required by Gas Works—Technical Gas Analysis—Gas Referees' Instructions, etc. etc.

Gas and Oil Engines.—*Gas, Gasoline and Oil Vapour Engines*: a New Book Descriptive of their Theory and Power, illustrating their Design, Construction and Operation for Stationary, Marine and Vehicle Motive Power. Designed for the general information of every one interested in this new and popular Prime Mover. By G. D. HISCOX, M.E. *Numerous engravings*, 8vo, cloth, 12*s*. 6*d*.

Gas Engines.—*A Practical Handbook on the Care and Management of Gas Engines.* By G. LIECKFELD, C.E. Authorised Translation by G. RICHMOND, M.E. With instructions for running Oil Engines. 16mo, cloth, 3*s*. 6*d*.

Gas Engineering.—*Manual for Gas Engineering Students.* By D. LEE. 18mo, cloth, 1*s*.

Gas Works.—*Gas Works*: their Arrangement, Construction, Plant, and Machinery. By F. COLYER, M. Inst. C.E. *With* 31 *folding plates*, 8vo, cloth, 12*s*. 6*d*.

Gold Mining.—*Practical Gold-Mining*: a Comprehensive Treatise on the Origin and Occurrence of Gold-bearing Gravels, Rocks and Ores, and the Methods by which the Gold is extracted. By C. G. WARNFORD LOCK, co-Author of 'Gold: its Occurrence and Extraction.' *With* 8 *plates and* 275 *engravings in the text*, 788 pp., royal 8vo, cloth, 2*l*. 2*s*.

Graphic Statics.—*The Elements of Graphic Statics.* By Professor KARL VON OTT, translated from the German by G. S. CLARKE, Capt. R.E., Instructor in Mechanical Drawing, Royal Indian Engineering College. *With* 93 *illustrations*, crown 8vo, cloth, 5*s*.

Graphic Statics.—*The Principles of Graphic Statics.* By GEORGE SYDENHAM CLARKE, Capt. Royal Engineers. *With* 112 *illustrations*. Third edition, 4to, cloth, 12*s*. 6*d*.

Graphic Statics.—*A New Method of Graphic Statics*, applied in the construction of Wrought-Iron Girders, practically illustrated by a series of Working Drawings of modern type. By EDMUND OLANDER, of the Great Western Railway, Assoc. Mem. Inst. C.E. Small folio, cloth, 10*s.* 6*d.*

Heat Engine.—*Theory and Construction of a Rational Heat Motor.* Translated from the German of RUDOLF DIESEL by BRYAN DONKIN, Mem. Inst. C.E. *Numerous cuts and plates*, 8vo, cloth, 6*s.*

Hot Water.—*Hot Water Supply:* a Practical Treatise upon the Fitting of Circulating Apparatus in connection with Kitchen Range and other Boilers, to supply Hot Water for Domestic and General Purposes. With a Chapter upon Estimating. By F. DYE. *With illustrations*, crown 8vo, cloth, 3*s.*

Hot Water.—*Hot Water Apparatus:* an Elementary Guide for the Fitting and Fixing of Boilers and Apparatus for the Circulation of Hot Water for Heating and for Domestic Supply, and containing a Chapter upon Boilers and Fittings for Steam Cooking. By F. DYE. 32 *illustrations*, fcap. 8vo, cloth, 1*s.* 6*d.*

Household Manual.—*Spons' Household Manual:* a Treasury of Domestic Receipts and Guide for Home Management. Demy 8vo, cloth, containing 975 pages and 250 *illustrations*, price 7*s.* 6*d.*

PRINCIPAL CONTENTS:

Hints for selecting a good House—Sanitation—Water Supply—Ventilation and Warming—Lighting—Furniture and Decoration—Thieves and Fire—The Larder—Curing Foods for lengthened Preservation—The Dairy—The Cellar—The Pantry—The Kitchen—Receipts for Dishes—The Housewife's Room—Housekeeping, Marketing—The Dining-Room—The Drawing-Room—The Bedroom—The Nursery—The Sick-Room—The Bath-Room—The Laundry—The School-Room—The Playground—The Work-Room—The Library—The Garden—The Farmyard—Small Motors—Household Law.

House Hunting.—*Practical Hints on Taking a House.* By H. PERCY BOULNOIS, Mem. Inst. C.E., City Engineer, Liverpool, Author of 'The Municipal and Sanitary Engineer's Handbook,' 'Dirty Dustbins and Sloppy Streets,' &c. 18mo, cloth, 1*s.* 6*d.*

Hydraulics.—*Simple Hydraulic Formulæ.* By T. W. STONE, C.E., late Resident District Engineer, Victoria Water Supply. Crown 8vo, cloth, 4*s.*

Hydraulic Machinery.—*Hydraulic Steam and Hand-Power Lifting and Pressing Machinery.* By FREDERICK COLYER, M. Inst. C.E., M. Inst. M.E. Second edition, revised and enlarged. *With* 88 *plates*, 8vo, cloth, 28*s.*

Hydraulic Machinery.—*Hydraulic Machinery.* With an Introduction to Hydraulics. By ROBERT GORDON BLAINE, Assoc. M. Inst. C.E., &c. *With* 272 *illustrations*, 383 pp. 8vo, cloth, 14*s.*

Hydraulic Motors.—*Water or Hydraulic Motors.*

By PHILIP R. BJÖRLING. *With 206 illustrations*, crown 8vo, cloth, 9*s.*

CONTENTS:

1. Introduction—2. Hydraulics relating to Water Motors—3. Water-wheels—4. Breast Water-wheels—5. Overshot and High-breast Water-wheels—6. Pelton Water-wheels—7. General Remarks on Water-wheels—8. Turbines—9. Outward-flow Turbines—10. Inward-flow Turbines—11. Mixed-flow Turbines—12. Parallel-flow Turbines—13. Circumferential-flow Turbines—14. Regulation of Turbines—15. Details of Turbines—16. Water-pressure or Hydraulic Engines—17. Reciprocating Water-pressure Engines—18. Rotative Water-pressure Engines—19. Oscillating Water-pressure Engines—20. Rotary Water-pressure Engines—21. General Remarks and Rules for Water-pressure Engines—22. Hydraulic Rams—23. Hydraulic Rams without Air Vessel in Direct Communication with the Drive Pipe—24. Hydraulic Rams with Air Vessel in Direct Communication with the Drive Pipe—25. Hydraulic Pumping Rams—26. Hydraulic Ram Engines—27. Details of Hydraulic Rams—28. Rules, Formulas, and Tables for Hydraulic Rams—29. Measuring Water in a Stream and over a Weir—Index.

Hydropathic Establishments.—*The Hydropathic Establishment and its Baths.*

By R. O. ALLSOP, Architect. Author of 'The Turkish Bath.' *Illustrated with plates and sections*, 8vo, cloth, 5*s.*

CONTENTS:

General Considerations—Requirements of the Hydropathic Establishment—Some existing Institutions—Baths and Treatments and the arrangement of the Bath-House—Vapour Baths and the Russian Bath—The Douche Room and its appliances—Massage and Electrical Treatment—Pulverisation and the Mont Dore Cure—Inhalation and the Pine Cure—The Sun Bath.

Ice Making.—*Theoretical and Practical Ammonia Refrigeration*,

a work of Reference for Engineers and others employed in the management of Ice and Refrigeration Machinery. By ILTYD L. REDWOOD, Assoc. Mem. Am. Soc. of M.E., Mem. Soc. Chemical Industry. *With 25 pages of tables.* Square 16mo, cloth, 4*s.* 6*d.*

Indicator.—*Twenty Years with the Indicator.*

By THOMAS PRAY, Jun., C.E., M.E., Member of the American Society of Civil Engineers. *With illustrations*, royal 8vo, cloth, 10*s.* 6*d.*

Indicator.—*A Treatise on the Richards Steam-Engine Indicator and the Development and Application of Force in the Steam-Engine.*

By CHARLES T. PORTER. *With illustrations.* Fourth edition, revised and enlarged, 8vo, cloth, 9*s.*

Induction Coils. — *Induction Coils and Coil Making*:

a Treatise on the Construction and Working of Shock, Medical and Spark Coils. By F. C. ALLSOP. Second edition, *with 125 illustrations*, crown 8vo, cloth, 3*s.* 6*d.*

Iron.—*The Mechanical and other Properties of Iron and Steel in connection with their Chemical Composition.*

By A. VOSMAER, Engineer. Crown 8vo, cloth, 6*s.*

CONTENTS:

The metallurgical behaviour of Carbon with Iron and Steel, also Manganese—Silicon—Phosphorus — Sulphur—Copper—Chromium — Titanium—Tungsten—Aluminium—Nickel—Cobalt—Arsenic—Analyses of Iron and Steel, &c.

Iron Manufacture.—*Roll-Turning for Sections in Steel and Iron*, working drawings for Rails, Sleepers, Girders, Bulbs, Ties, Angles, &c., also Blooming and Cogging for Plates and Billets. By ADAM SPENCER. Second edition, *with 78 large plates*. Illustrations of nearly every class of work in this Industry. 4to, cloth, 1*l.* 10*s.*

Locomotive.—*The Construction of the Modern Locomotive.* By GEORGE HUGHES, Assistant in the Chief Mechanical Engineer's Department, Lancashire and Yorkshire Railway. *Numerous engravings*, 8vo, cloth, 9*s.*

CONTENTS:

The Boiler—The Foundry—the Use of Steel Castings—Brass Foundry—The Forge—Smithy, including Springs—Coppersmiths' Work—The Machine Shop—Erecting.

Lime and Cement.—*A Manual of Lime and Cement*, their treatment and use in construction. By A. H. HEATH. Crown 8vo, cloth, 6*s.*

Liquid Fuel.—*Liquid Fuel for Mechanical and Industrial Purposes.* Compiled by E. A. BRAYLEY HODGETTS. *With wood engravings.* 8vo, cloth, 5*s.*

Machinery Repairs.—*The Repair and Maintenance of Machinery*; a Handbook of Practical Notes and Memoranda for Engineers and Machinery Users. By T. W. BARBER, C.E., M.E., Author of 'The Engineers' Sketch Book.' *With about 400 illustrations*, 8vo, cloth, 10*s.* 6*d.*

Mechanical Engineering.—*Handbook for Mechanical Engineers.* By HENRY ADAMS, Professor of Engineering at the City of London College, Mem. Inst. C.E., Mem. Inst. M.E., &c. Fourth edition, revised and enlarged. Crown 8vo, cloth, 7*s.* 6*d.*

CONTENTS:

Fundamental Principles of Mechanics—Varieties and Properties of Materials—Strength of Materials and Structures—Pattern Making—Moulding and Founding—Forging, Welding and Riveting—Workshop Tools and General Machinery—Transmission of Power, Friction and Lubrication—Thermodynamics and Steam—Steam Boilers—The Steam Engine—Hydraulic Machinery—Electrical Engineering—Sundry Notes and Tables.

Mechanical Engineering.—*The Mechanician*: a Treatise on the Construction and Manipulation of Tools, for the use and instruction of Young Engineers and Scientific Amateurs, comprising the Arts of Blacksmithing and Forging; the Construction and Manufacture of Hand Tools, and the various Methods of Using and Grinding them; description of Hand and Machine Processes; Turning and Screw Cutting. By CAMERON KNIGHT, Engineer. *Containing 1147 illustrations*, and 397 pages of letter-press. Fourth edition, 4to, cloth, 18*s.*

Mechanical Movements.—*The Engineers' Sketch-Book of Mechanical Movements, Devices, Appliances, Contrivances, Details employed in the Design and Construction of Machinery for every purpose.* Collected from numerous Sources and from Actual Work. Classified and Arranged for Reference. *With* 2600 *Illustrations.* By T. W. BARBER, Engineer. Third edition, 8vo, cloth, 10*s.* 6*d.*

Metal Plate Work.—*Metal Plate Work: its Patterns and their Geometry.* Also Notes on Metals and Rules in Mensuration for the use of Tin, Iron, and Zinc Plate-workers, Coppersmiths, Boiler-makers and Plumbers. By C. T. MILLIS, M.I.M.E. Second edition, considerably enlarged. *With numerous illustrations.* Crown 8vo, cloth, 9*s.*

Metrical Tables.—*Metrical Tables.* By Sir G. L. MOLESWORTH, M.I.C.E. Third edition, revised and enlarged, 32mo, cloth, 2*s.*

Mill-Gearing.—*A Practical Treatise on Mill-Gearing, Wheels, Shafts, Riggers, etc.*; for the use of Engineers. By THOMAS BOX. Third edition, *with* 11 *plates.* Crown 8vo, cloth, 7*s.* 6*d.*

Mill-Gearing.—*The Practical Millwright and Engineer's Ready Reckoner;* or Tables for finding the diameter and power of cog-wheels, diameter, weight, and power of shafts, diameter and strength of bolts, etc. By THOMAS DIXON. Fourth edition, 12mo, cloth, 3*s.*

Mineral Oils.—*A Practical Treatise on Mineral Oils and their By-Products,* including a Short History of the Scotch Shale Oil Industry, the Geological and Geographical Distribution of Scotch Shales, Recovery of Acid and Soda used in Oil Refining, and a list of Patents relating to Mineral Oils. By ILTYD I. REDWOOD, Mem. Soc. Chemical Industry. 8vo, cloth, 15*s.*

Miners' Pocket-Book.—*Miners' Pocket-Book;* a Reference Book for Miners, Mine Surveyors, Geologists, Mineralogists, Millmen, Assayers, Metallurgists, and Metal Merchants all over the world. By C. G. WARNFORD LOCK, author of 'Practical Gold Mining,' 'Mining and Ore-Dressing Machinery,' &c. Second edition, fcap. 8vo, roan, gilt edges, 12*s.* 6*d.*

CONTENTS:

Motive Power—Dams and Reservoirs—Transmitting Power—Weights and Measures—Prospecting—Boring—Drilling—Blasting—Explosives—Shaft Sinking—Pumping—Ventilating—Lighting—Coal Cutting—Hauling and Hoisting—Water Softening—Stamp Batteries—Crushing Rolls—Jordan's Centrifugal Process—River Mining—Ore Dressing—Gold, Silver, Copper Smelting—Treatment of Ores—Coal Cleaning—Mine Surveying—British Rocks—Geological Maps—Mineral Veins—Mining Methods—Coal Seams—Minerals—Precious Stones—Metals and Metallic Ores—Metalliferous Minerals—Assaying—Glossary—List of Useful Books—Index, &c., &c., &c.

Mining and Ore-Dressing Machinery.—By C. G. WARNFORD LOCK, Author of 'Practical Gold Mining.' *Numerous illustrations*, super-royal 4to, cloth, 25*s.*

Mining.—*Economic Mining;* a Practical Handbook for the Miner, the Metallurgist, and the Merchant. By C. G. WARNFORD LOCK, Mem. Inst. of Mining and Metallurgy, Author of 'Practical Gold Mining.' *With illustrations*, 8vo, cloth, 21*s.*

Municipal Engineering. — *The Municipal and Sanitary Engineer's Handbook.* By H. PERCY BOULNOIS, Mem. Inst. C.E., Borough Engineer, Portsmouth. *With numerous illustrations.* Third edition, re-written, demy 8vo, cloth, 15*s.*

CONTENTS:

The Appointment and Duties of the Town Surveyor—Traffic—Macadamised Roadways—Steam Rolling—Road Metal and Breaking—Pitched Pavements—Asphalte—Wood Pavements—Footpaths—Kerbs and Gutters—Street Naming and Numbering—Street Lighting—Sewerage—Ventilation of Sewers—Disposal of Sewage—House Drainage—Disinfection—Gas and Water Companies, etc., Breaking up Streets—Improvement of Private Streets—Borrowing Powers—Artizans' and Labourers' Dwellings—Public Conveniences—Scavenging, including Street Cleansing—Watering and the Removing of Snow—Planting Street Trees—Deposit of Plans—Dangerous Buildings—Hoardings—Obstructions—Improving Street Lines—Cellar Openings—Public Pleasure Grounds—Cemeteries—Mortuaries—Cattle and Ordinary Markets—Public Slaughter-houses, etc.—Giving numerous Forms of Notices, Specifications, and General Information upon these and other subjects of great importance to Municipal Engineers and others engaged in Sanitary Work.

Paints. — *Pigments, Paint and Painting.* A Practical Book for Practical Men. By GEORGE TERRY. *With illustrations*, crown 8vo, cloth, 7*s.* 6*d.*

Paper Manufacture.—*A Text-Book of Paper-Making.* By C. F. CROSS and E. J. BEVAN. *With engravings*, crown 8vo, cloth. New edition in the press.

Perfumery. — *Perfumes and their Preparation,* containing complete directions for making Handkerchief Perfumes, Smelling Salts, Sachets, Fumigating Pastils, Preparations for the care of the Skin, the Mouth, the Hair, and other Toilet articles, with a detailed description of aromatic substances, their nature, tests of purity, and wholesale manufacture. By G. W. ASKINSON, Dr. Chem. *With* 32 *engravings*, 8vo, cloth, 12*s.* 6*d.*

Perspective. — *Perspective, Explained and Illustrated.* By G. S. CLARKE, Capt. R.E. *With illustrations*, 8vo, cloth, 3*s.* 6*d.*

Phonograph.—*The Phonograph, and How to Construct it.* With a Chapter on Sound. By W. GILLETT. *With engravings and full working drawings*, crown 8vo, cloth, 5*s.*

Popular Engineering.—*Popular Engineering, being interesting and instructive examples in Civil, Mechanical, Electrical, Chemical, Mining, Military and Naval Engineering*, graphically and plainly described, and specially written for those about to enter the Engineering Profession and the Scientific Amateur, with chapters on Perpetual Motion and Engineering Schools and Colleges. By F. DYE. *With 700 illustrations*, crown 4to, cloth, *7s. 6d.*

Plumbing.—*Plumbing, Drainage, Water Supply and Hot Water Fitting.* By JOHN SMEATON, C.E., M.S.A., R.P., Examiner to the Worshipful Plumbers' Company. *Numerous engravings*, 8vo, cloth, *7s. 6d.*

Pumping Engines.—*Practical Handbook on Direct-acting Pumping Engine and Steam Pump Construction.* By PHILIP R. BJÖRLING. *With 20 plates*, crown 8vo, cloth, *5s.*

Pumps.—*A Practical Handbook on Pump Construction.* By PHILIP R. BJÖRLING. *Plates*, crown 8vo, cloth, *5s.*

CONTENTS:

Principle of the action of a Pump—Classification of Pumps—Description of various classes of Pumps—Remarks on designing Pumps—Materials Pumps should be made of for different kinds of Liquids—Description of various classes of Pump-valves—Materials Pump-valves should be made of for different kinds of Liquids—Various Classes of Pump-buckets—On designing Pump-buckets—Various Classes of Pump-pistons—Cup-leathers—Air-vessels—Rules and Formulas, &c., &c.

Pumps.—*Pump Details. With 278 illustrations.* By PHILIP R. BJÖRLING, author of a Practical Handbook on Pump Construction. Crown 8vo, cloth, *7s. 6d.*

CONTENTS:

Windbores—Foot-valves and Strainers—Clack-pieces, Bucket-door-pieces, and H-pieces Working-barrels and Plunger-cases—Plungers or Rams—Piston and Plunger, Bucket and Plunger, Buckets and Valves—Pump-rods and Spears, Spear-rod Guides, &c.—Valve-swords, Spindles, and Draw-hooks—Set-offs or Off-sets—Pipes, Pipe-joints, and Pipe-stays—Pump-slings—Guide-rods and Guides, Kites, Yokes, and Connecting-rods—L Bobs, T Bobs, Angle or V Bobs, and Balance-beams, Rock-arms, and Fend-off Beams, Cisterns, and Tanks—Minor Details.

Pumps.—*Pumps and Pumping Machinery.* By F. COLYER, Mem. Inst. C.E., Mem. Inst. M.E. Part I., second edition, revised and enlarged, *with 50 plates*, 8vo, cloth, *1l. 8s.* Part II., *12s. 6d.*

CONTENTS:

Three-throw Lift and Well Pumps—Tonkin's Patent "Cornish" Steam Pump—Thornewill and Warham's Steam Pump—Water Valves—Water Meters—Centrifugal Pumping Machinery—Airy and Anderson's Spiral Pumps—Blowing Engines—Air Compressors—Horizontal High-pressure Engines—Horizontal Compound Engines—Reidler Engine—Vertical Compound Pumping Engines—Compound Beam Pumping Engines—Shonheyder's Patent Regulator—Cornish Beam Engines—Worthington High-duty Pumping Engine—Davy's Patent Differential Pumping Engine—Tonkin's Patent Pumping Engine—Lancashire Boiler—Babcock and Wilcox Water-tube Boilers.

Pumps. — *Pumps, Historically, Theoretically, and Practically Considered.* By P. R. BJÖRLING. *With* 156 *illustrations.* Crown 8vo, cloth, 7*s.* 6*d.*

Quantities.—*A Complete Set of Contract Documents for a Country Lodge,* comprising Drawings, Specifications, Dimensions (for quantities), Abstracts, Bill of Quantities, Form of Tender and Contract, with Notes by J. LEANING, printed in facsimile of the original documents, on single sheets fcap., in linen case, 5*s.*

Quantity Surveying.—*Quantity Surveying.* By J. LEANING. With 68 illustrations. Third edition, revised, demy 8vo, cloth, 15*s.*

CONTENTS:

A complete Explanation of the London Practice.
General Instructions.
Order of Taking Off.
Modes of Measurement of the various Trades.
Use and Waste.
Ventilation and Warming.
Credits, with various Examples of Treatment.
Abbreviations.
Squaring the Dimensions.
Abstracting, with Examples in illustration of each Trade.
Billing.
Examples of Preambles to each Trade.
Form for a Bill of Quantities.
Do. Bill of Credits.
Do. Bill for Alternative Estimate.
Restorations and Repairs, and Form of Bill.
Variations before Acceptance of Tender.
Errors in a Builder's Estimate.
Schedule of Prices.
Form of Schedule of Prices.
Analysis of Schedule of Prices.
Adjustment of Accounts.
Form of a Bill of Variations.
Remarks on Specifications.
Prices and Valuation of Work, with Examples and Remarks upon each Trade.
The Law as it affects Quantity Surveyors, with Law Reports.
Taking Off after the Old Method.
Northern Practice.
The General Statement of the Methods recommended by the Manchester Society of Architects for taking Quantities.
Examples of Collections.
Examples of "Taking Off" in each Trade.
Remarks on the Past and Present Methods of Estimating.

Railway Curves.—*Tables for Setting out Curves for Railways, Canals, Roads, etc.,* varying from a radius of five chains to three miles. By A. KENNEDY and R. W. HACKWOOD. *Illustrated,* 32mo, cloth, 2*s.* 6*d.*

Roads.—*The Maintenance of Macadamised Roads.* By T. CODRINGTON, M.I.C.E., F.G.S., General Superintendent of County Roads for South Wales. Second edition, 8vo, cloth, 7*s.* 6*d.*

Scamping Tricks.—*Scamping Tricks and Odd Knowledge occasionally practised upon Public Works,* chronicled from the confessions of some old Practitioners. By JOHN NEWMAN, Assoc. M. Inst. C.E., author of 'Earthwork Slips and Subsidences upon Public Works,' 'Notes on Concrete,' &c. Crown 8vo, cloth, 2*s.* 6*d.*

Screw Cutting.—*Turners' Handbook on Screw Cutting, Coning, etc., etc.,* with Tables, Examples, Gauges, and Formulæ. By WALTER PRICE. Fcap. 8vo, cloth, 1*s.*

Screw Cutting.—*Screw Cutting Tables for Engineers and Machinists*, giving the values of the different trains of Wheels required to produce Screws of any pitch, calculated by Lord LINDSAY. Oblong, cloth, *2s.*

Screw Cutting.—*Screw Cutting Tables*, for the use of Mechanical Engineers, showing the proper arrangement of Wheels for cutting the Threads of Screws of any required pitch, with a Table for making the Universal Gas-pipe Threads and Taps. By W. A. MARTIN, Engineer. Second edition, oblong, cloth, *1s.*

Sewerage.—*Sewerage and Sewage Disposal.* By HENRY ROBINSON, Mem. Inst. C.E., F.G.S., Professor of Civil Engineering, King's College, London, &c., with large folding plate. Demy 8vo, cloth, *12s. 6d.*

Slide Valve.—*A Treatise on a Practical Method of Designing Slide-Valve Gears by Simple Geometrical Construction*, based upon the principles enunciated in Euclid's Elements, and comprising the various forms of Plain Slide-Valve and Expansion Gearing; together with Stephenson's, Gooch's, and Allan's Link-Motions, as applied either to reversing or to variable expansion combinations. By EDWARD J. COWLING WELCH, Mem. Inst. M.E. Crown 8vo, cloth, *6s.*

Soap.—*A Treatise on the Manufacture of Soap and Candles, Lubricants and Glycerine.* By W. LANT CARPENTER, B.A., B.Sc. *With illustrations*, new edition, revised, crown 8vo, *12s. 6d.*

Stair Building.—*Practical Stair Building and Handrailing by the Square Section and Falling Line System.* By W. H. WOOD. *Folding plates*, post 4to, cloth, *10s. 6d.*

Steam Boilers.—*Steam Boilers, their Management and Working on land and sea.* By JAMES PEATTIE. *With illustrations*, crown 8vo, cloth, *5s.*

Steam Engine.—*A Practical Treatise on the Steam Engine*, containing Plans and Arrangements of Details for Fixed Steam Engines, with Essays on the Principles involved in Design and Construction. By ARTHUR RIGG, Engineer, Member of the Society of Engineers and of the Royal Institution of Great Britain. Demy 4to, *copiously illustrated with woodcuts and 103 plates*, in one Volume. Second edition, cloth, *25s.*

This work is not, in any sense, an elementary treatise, or history of the steam engine, but is intended to describe examples of Fixed Steam Engines without entering into the wide domain of locomotive or marine practice. To this end illustrations will be given of the most recent arrangements of Horizontal, Vertical, Beam, Pumping, Winding, Portable, Semi-portable, Corliss, Allen, Compound, and other similar Engines, by the most eminent Firms in Great Britain and America. The laws relating to the action and precautions to be observed in the construction of the various details, such as Cylinders, Pistons, Piston-rods, Connecting-

rods, Cross-heads, Motion-blocks, Eccentrics, Simple, Expansion, Balanced, and Equilibrium Slide-valves, and Valve-gearing will be minutely dealt with. In this connection will be found articles upon the Velocity of Reciprocating Parts and the Mode of Applying the Indicator, Heat and Expansion of Steam Governors, and the like. It is the writer's desire to draw illustrations from every possible source, and give only those rules that present practice deems correct.

Steam Engine.—*The Steam Engine considered as a Thermodynamic Machine*, a treatise on the Thermodynamic efficiency of Steam Engines, illustrated by Tables, Diagrams, and Examples from Practice. By JAS. H. COTTERILL, M.A., F.R.S., Professor of Applied Mechanics in the Royal Naval College. Third edition, revised and enlarged, 8vo, cloth, 15*s.*

Steam Engine.—*Steam Engine Management;* a Treatise on the Working and Management of Steam Boilers. By F. COLYER, M. Inst. C.E., Mem. Inst. M.E. New edition, 18mo, cloth, 3*s.* 6*d.*

Steam Engine.—*A Treatise on Modern Steam Engines and Boilers*, including Land, Locomotive and Marine Engines and Boilers, for the use of Students. By FREDERICK COLYER, M. Inst. C.E., Mem. Inst. M.E. *With* 36 *plates.* 4to, cloth, 12*s.* 6*d.*

Sugar.—*Tables for the Quantitative Estimation of the Sugars*, with Explanatory Notes. By Dr. ERNEST WEIN; translated, with additions, by WILLIAM FREW, Ph.D. Crown 8vo, cloth, 6*s.*

Sugar.—*A Handbook for Planters and Refiners;* being a comprehensive Treatise on the Culture of Sugar-yielding Plants, and on the Manufacture, Refining, and Analysis of Cane, Palm, Maple, Melon, Beet, Sorghum, Milk, and Starch Sugars; with copious Statistics of their Production and Commerce, and a chapter on the Distillation of Rum. By C. G. WARNFORD LOCK, F.L.S., &c.; B. E. R. NEWLANDS, F.C.S., F.I.C., Mem. Council Soc. Chemical Industry; and J. A. R. NEWLANDS, F.C.S., F.I.C. *Upwards of* 200 *illustrations and many plates*, 8vo, cloth, 1*l.* 10*s.*

Surveying.—*A Practical Treatise on the Science of Land and Engineering Surveying, Levelling, Estimating Quantities, etc.*, with a general description of the several Instruments required for Surveying, Levelling, Plotting, etc. By H. S. MERRETT. Fourth edition, revised by G. W. USILL, Assoc. Mem. Inst. C.E. 41 *plates, with illustrations and tables*, royal 8vo, cloth, 12*s.* 6*d.*

Surveying and Levelling. — *Surveying and Levelling Instruments theoretically and practically described*, for construction, qualities, selection, preservation, adjustments, and uses, with other apparatus and appliances used by Civil Engineers and Surveyors. By W. F. STANLEY. Second edition. 350 *cuts*, crown 8vo, cloth, 7*s.* 6*d.*

Tables of Logarithms.—*A B C Five-Figure Logarithms for general use.* By C. J. WOODWARD, B.Sc. Containing Mantissæ of numbers to 10,000. Log. Sines, Tangents, Cotangents, and Cosines to 10″ of Arc. Together with full explanations and simple exercises showing use of the tables. 4*s.*

Tables of Squares.—*Barlow's Tables of Squares, Cubes, Square Roots, Cube Roots, Reciprocals of all Integer Numbers up to* 10,000. Post 8vo, cloth, 6*s.*

Telephones. — *Telephones, their Construction and Fitting.* By F. C. ALLSOP. Fourth edition, revised. *With* 210 *illustrations.* Crown 8vo, cloth, 5*s.*

Tobacco Cultivation.—*Tobacco Growing, Curing, and Manufacturing;* a Handbook for Planters in all parts of the world. Edited by C. G. WARNFORD LOCK, F.L.S. *With illustrations.* Crown 8vo, cloth, 7*s.* 6*d.*

Tropical Agriculture.—*Tropical Agriculture:* a Treatise on the Culture, Preparation, Commerce and Consumption of the principal Products of the Vegetable Kingdom. By P. L. SIMMONDS, F.L.S., F.R.C.I. New edition, revised and enlarged, 8vo, cloth, 21*s.*

Turning.—*The Practice of Hand Turning in Wood, Ivory, Shell, etc.*, with Instructions for Turning such Work in Metal as may be required in the Practice of Turning in Wood, Ivory, etc.; also an Appendix on Ornamental Turning. (A book for beginners.) By FRANCIS CAMPIN. Third edition, *with wood engravings*, crown 8vo, cloth, 3*s.* 6*d.*

Valve Gears. — *Treatise on Valve-Gears*, with special consideration of the Link-Motions of Locomotive Engines. By Dr. GUSTAV ZEUNER, Professor of Applied Mechanics at the Confederated Polytechnikum of Zurich. Translated from the Fourth German Edition, by Professor J. F. KLEIN, Lehigh University, Bethlehem, Pa. *Illustrated*, 8vo, cloth, 12*s.* 6*d.*

Varnish.—*The practical Polish and Varnish-Maker;* a Treatise containing 750 practical Receipts and Formulæ for the Manufacture of Polishes, Lacquers, Varnishes, and Japans of all kinds, for workers in Wood and Metal, and directions for using same. By H. C. STANDAGE (Practical Chemist), author of 'The Artist's Manual of Pigments.' Crown 8vo, cloth, 6*s.*

Ventilation.—*Health and Comfort in House Building;* or, Ventilation with Warm Air by Self-acting Suction Power. With Review of the Mode of Calculating the Draught in Hot-air Flues, and with some Actual Experiments by J. DRYSDALE, M.D., and J. W. HAYWARD, M.D. *With plates and woodcuts.* Third edition, with some New Sections, and the whole carefully revised, 8vo, cloth, 7*s.* 6*d.*

Warming and Ventilating.—*A Practical Treatise upon Warming Buildings by Hot Water*, and upon Heat and Heating Appliances in general; with an inquiry respecting Ventilation, the cause and action of Draughts in Chimneys and Flues, and the laws relating to Combustion. By CHARLES HOOD, F.R.S. Re-written by FREDERICK DYE. Third edition. 8vo, cloth, 15*s.*

Watchwork.—*Treatise on Watchwork, Past and Present.* By the Rev. H. L. NELTHROPP, M.A., F.S.A. *With 32 illustrations*, crown 8vo, cloth, 6*s.* 6*d.*

CONTENTS:

Definitions of Words and Terms used in Watchwork—Tools—Time—Historical Summary—On Calculations of the Numbers for Wheels and Pinions; their Proportional Sizes, Trains, etc.—Of Dial Wheels, or Motion Work—Length of Time of Going without Winding up—The Verge—The Horizontal—The Duplex—The Lever—The Chronometer—Repeating Watches—Keyless Watches—The Pendulum, or Spiral Spring—Compensation—Jewelling of Pivot Holes—Clerkenwell—Fallacies of the Trade—Incapacity of Workmen—How to Choose and Use a Watch, etc.

Water Softening.—*Water Softening and Purification:* the Softening and Clarification of Hard and Dirty Waters. By HAROLD COLLET. Crown 8vo, cloth, 5*s.*

Waterworks.—*The Principles of Waterworks Engineering.* By J. H. T. TUDSBERY, D.Sc., Hunter Medallist of Glasgow University, M. Inst. C.E., and A. W. BRIGHTMORE, M.Sc., Assoc. M. Inst. C.E. Second edition, *with illustrations and* 13 *plates*, medium 8vo, cloth, 25*s.*

Well Sinking.—*Well Sinking.* The modern practice of Sinking and Boring Wells, with geological considerations and examples of Wells. By ERNEST SPON, Assoc. Mem. Inst. C.E. Second edition, revised and enlarged. Crown 8vo, cloth, 10*s.* 6*d.*

Wiring.—*Incandescent Wiring Hand-Book.* By F. B. BADT, late 1st Lieut. Royal Prussian Artillery. *With* 41 *illustrations and* 5 *tables.* 18mo, cloth, 4*s.* 6*d.*

Wood-working Factories.—*On the Arrangement, Care, and Operation of Wood-working Factories and Machinery*, forming a complete Operator's Handbook. By J. RICHARD, Mechanical Engineer. Second edition, revised, *woodcuts*, crown 8vo, cloth, 5*s.*

SPONS' DICTIONARY OF ENGINEERING,

CIVIL, MECHANICAL, MILITARY, & NAVAL,

WITH

Technical Terms in French, German, Italian, and Spanish.

In 97 numbers, Super-royal 8vo, containing 3132 *printed pages* and 7414 *engravings*. **Any number can be had separate:** Nos. 1 to 95 *1s.* each, post free; Nos. 96, 97, *2s.*, post free.

COMPLETE LIST OF ALL THE SUBJECTS:

	Nos.
Abacus	1
Adhesion	1
Agricultural Engines	1 and 2
Air-Chamber	2
Air Pump	2
Algebraic Signs	2
Alloy	2
Aluminium	2
Amalgamating Machine	2
Ambulance	2
Anchors	2
Anemometer	2 and 3
Angular Motion	3 and 4
Angle-iron	3
Angle of Friction	3
Animal Charcoal Machine	4
Antimony, 4; Anvil	4
Aqueduct, 4; Arch	4
Archimedean Screw	4
Arming Press	4 and 5
Armour, 5; Arsenic	5
Artesian Well	5
Artillery, 5 and 6; Assaying	6
Atomic Weights	6 and 7
Auger, 7; Axles	7
Balance, 7; Ballast	7
Bank Note Machinery	7
Barn Machinery	7 and 8
Barker's Mill	8
Barometer, 8; Barracks	8
Barrage	8 and 9
Battery	9 and 10
Bell and Bell-hanging	10
Belts and Belting	10 and 11
Bismuth	11
Blast Furnace	11 and 12
Blowing Machine	12
Body Plan	12 and 13
Boilers	13, 14, 15
Bond	15 and 16
Bone Mill	16
Boot-making Machinery	16
Boring and Blasting	16 to 19
Brake	19 and 20
Bread Machine	20
Brewing Apparatus	20 and 21
Brick-making Machines	21
Bridges	21 to 28
Buffer	28
Cables	28 and 29
Cam, 29; Canal	29
Candles	29 and 30
Cement, 30; Chimney	30
Coal Cutting and Washing Machinery	31
Coast Defence	31, 32
Compasses	32
Construction	32 and 33
Cooler, 34; Copper	34
Cork cutting Machine	34

	Nos.
Corrosion	34 and 35
Cotton Machinery	35
Damming	35 to 37
Details of Engines ..	37, 38
Displacement	38
Distilling Apparatus ..	38 and 39
Diving and Diving Bells ..	39
Docks	39 and 40
Drainage	40 and 41
Drawbridge	41
Dredging Machine	41
Dynamometer	41 to 43
Electro-Metallurgy ..	43, 44
Engines, Varieties ..	44, 45
Engines, Agricultural ..	1 and 2
Engines, Marine	74, 75
Engines, Screw	89, 90
Engines, Stationary ..	91, 92
Escapement	45, 46
Fan	46
File-cutting Machine	46
Fire-arms	46, 47
Flax Machinery	47, 48
Float Water-wheels	48
Forging	48
Founding and Casting ..	48 to 50
Friction, 50; Friction, Angle of	3
Fuel, 50; Furnace ..	50, 51
Fuze, 51; Gas	51
Gearing	51, 52
Gearing Belt	10, 11
Geodesy	52 and 53
Glass Machinery	53
Gold, 53, 54; Governor	54
Gravity, 54; Grindstone ..	54
Gun-carriage, 54; Gun Metal ..	54
Gunnery	54 to 56
Gunpowder	56
Gun Machinery	56, 57
Hand Tools	57, 58
Hanger, 58; Harbour	58
Haulage, 58, 59; Hinging ..	59
Hydraulics and Hydraulic Machinery	59 to 63
Ice-making Machine	63
India-rubber	63
Indicator	63 and 64
Injector	64
Iron	64 to 67
Iron Ship Building	67
Irrigation	67 and 68
Isomorphism, 68; Joints ..	68
Keels and Coal Shipping	68 and 69
Kiln, 69; Knitting Machine ..	69
Kyanising	69
Lamp, Safety	69, 70
Lead	70
Lifts, Hoists	70, 71
Lights, Buoys, Beacons ..	71 and 72
Limes, Mortars, and Cements ..	72
Locks and Lock Gates ..	72, 73
Locomotive	73
Machine Tools	73, 74
Manganese	74
Marine Engine	74 and 75
Materials of Construction	75 and 76
Measuring and Folding	76
Mechanical Movements ..	76, 77
Mercury, 77; Metallurgy ..	77
Meter	77, 78
Metric System	78
Mills	78, 79
Molecule, 79; Oblique Arch ..	79
Ores, 79, 80; Ovens	80
Over-shot Water-wheel ..	80, 81
Paper Machinery	81
Permanent Way	81, 82
Piles and Pile-driving ..	82 and 83
Pipes	83, 84
Planimeter	84
Pumps	84 and 85
Quarrying	85
Railway Engineering ..	85 and 86
Retaining Walls	86
Rivers, 86, 87; Riveted Joint ..	87
Roads	87, 88
Roofs	88, 89
Rope-making Machinery ..	89
Scaffolding	89
Screw Engines	89, 90
Signals, 90; Silver ..	90, 91
Stationary Engine ..	91, 92
Stave-making & Cask Machinery	92
Steel, 92; Sugar Mill ..	92, 93
Surveying and Surveying Instruments	93, 94
Telegraphy	94, 95
Testing, 95; Turbine	95
Ventilation ..	95, 96, 97
Waterworks	96, 97
Wood-working Machinery	96, 97
Zinc	96, 97

In super-royal 8vo, 1168 pp., *with 2400 illustrations*, in 3 Divisions, cloth, price 13*s.* 6*d.* each; or 1 vol., cloth, 2*l.*; or half-morocco, 2*l.* 8*s.*

A SUPPLEMENT

TO

SPONS' DICTIONARY OF ENGINEERING.

EDITED BY ERNEST SPON, ASSOC. MEM. INST. C.E.

Abacus, Counters, Speed Indicators, and Slide Rule.
Agricultural Implements and Machinery.
Air Compressors.
Animal Charcoal Machinery.
Antimony.
Axles and Axle-boxes.
Barn Machinery.
Belts and Belting.
Blasting. Boilers.
Brakes.
Brick Machinery.
Bridges.
Cages for Mines.
Calculus, Differential and Integral.
Canals.
Carpentry.
Cast Iron.
Cement, Concrete, Limes, and Mortar.
Chimney Shafts.
Coal Cleansing and Washing.
Coal Mining.
Coal Cutting Machines.
Coke Ovens. Copper.
Docks. Drainage.
Dredging Machinery.
Dynamo - Electric and Magneto-Electric Machines.
Dynamometers.
Electrical Engineering, Telegraphy, Electric Lighting and its practical details, Telephones
Engines, Varieties of.
Explosives. Fans.
Founding, Moulding and the practical work of the Foundry.
Gas, Manufacture of.
Hammers, Steam and other Power.
Heat. Horse Power.
Hydraulics.
Hydro-geology.
Indicators. Iron.
Lifts, Hoists, and Elevators.
Lighthouses, Buoys, and Beacons.
Machine Tools.
Materials of Construction.
Meters.
Ores, Machinery and Processes employed to Dress.
Piers.
Pile Driving.
Pneumatic Transmission.
Pumps.
Pyrometers.
Road Locomotives.
Rock Drills.
Rolling Stock.
Sanitary Engineering.
Shafting.
Steel.
Steam Navvy.
Stone Machinery.
Tramways.
Well Sinking.

In demy 4to, handsomely bound in cloth, *illustrated with* 220 *full page plates*, Price 15*s*.

ARCHITECTURAL EXAMPLES

IN BRICK, STONE, WOOD, AND IRON.

A COMPLETE WORK ON THE DETAILS AND ARRANGEMENT OF BUILDING CONSTRUCTION AND DESIGN.

BY WILLIAM FULLERTON, ARCHITECT.

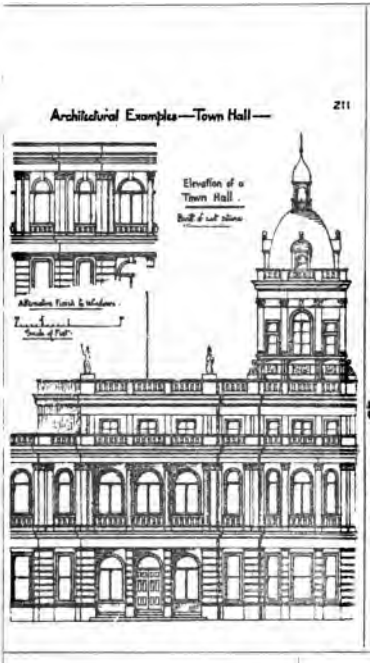
Containing 220 Plates, with numerous Drawings selected from the Architecture of Former and Present Times.

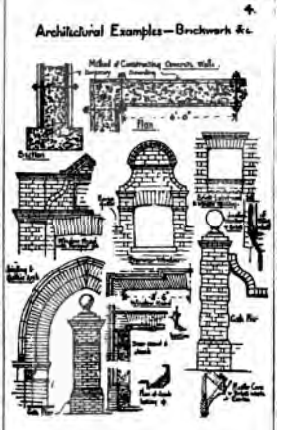
The Details and Designs are Drawn to Scale, $\frac{1}{8}$", $\frac{1}{4}$", $\frac{1}{2}$", and Full size being chiefly used.

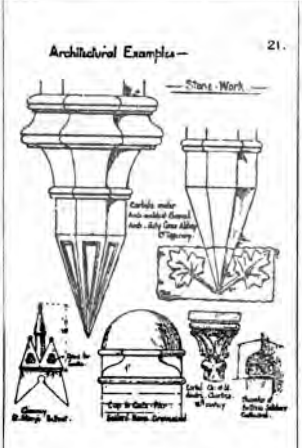
The Plates are arranged in Two Parts. The First Part contains Details of Work in the four principal Building materials, the following being a few of the subjects in this Part:—Various forms of Doors and Windows, Wood and Iron Roofs, Half Timber Work, Porches, Towers, Spires, Belfries, Flying Buttresses, Groining, Carving, Church Fittings, Constructive and Ornamental Iron Work, Classic and Gothic Molds and Ornament, Foliation Natural and Conventional, Stained Glass, Coloured Decoration, a Section to Scale of the Great Pyramid, Grecian and Roman Work, Continental and English Gothic, Pile Foundations, Chimney Shafts according to the regulations of the London County Council, Board Schools. The Second Part consists of Drawings of Plans and Elevations of Buildings, arranged under the following heads:—Workmen's Cottages and Dwellings, Cottage Residences and Dwelling Houses, Shops, Factories, Warehouses, Schools, Churches and Chapels, Public Buildings, Hotels and Taverns, and Buildings of a general character.

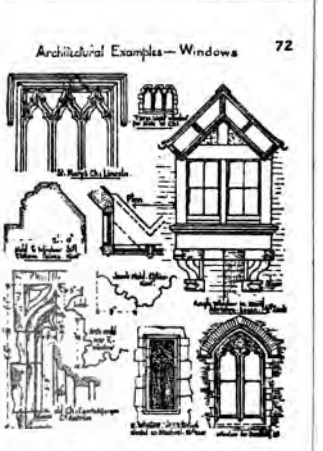
All the Plates are accompanied with particulars of the Work, with Explanatory Notes and Dimensions of the various parts.

Specimen Pages, reduced from the originals.









With nearly 1500 *illustrations*, in super-royal 8vo, in 5 Divisions, cloth. Divisions 1 to 4, 13*s.* 6*d.* each; Division 5, 17*s.* 6*d.*; or 2 vols., cloth, £3 10*s.*

SPONS' ENCYCLOPÆDIA

OF THE

INDUSTRIAL ARTS, MANUFACTURES, AND COMMERCIAL PRODUCTS.

EDITED BY C. G. WARNFORD LOCK, F.L.S.

Among the more important of the subjects treated of, are the following:—

Acids, 207 pp. 220 figs.
Alcohol, 23 pp. 16 figs.
Alcoholic Liquors, 13 pp.
Alkalies, 89 pp. 78 figs.
Alloys. Alum.
Asphalt. Assaying.
Beverages, 89 pp. 29 figs.
Blacks.
Bleaching Powder, 15 pp.
Bleaching, 51 pp. 48 figs.
Candles, 18 pp. 9 figs.
Carbon Bisulphide.
Celluloid, 9 pp.
Cements. Clay.
Coal-tar Products, 44 pp. 14 figs.
Cocoa, 8 pp.
Coffee, 32 pp. 13 figs.
Cork, 8 pp. 17 figs.
Cotton Manufactures, 62 pp. 57 figs.
Drugs, 38 pp.
Dyeing and Calico Printing, 28 pp. 9 figs.
Dyestuffs, 16 pp.
Electro-Metallurgy, 13 pp.
Explosives, 22 pp. 33 figs.
Feathers.
Fibrous Substances, 92 pp. 79 figs.
Floor-cloth, 16 pp. 21 figs.
Food Preservation, 8 pp.
Fruit, 8 pp.
Fur, 5 pp.
Gas, Coal, 8 pp.
Gems.
Glass, 45 pp. 77 figs.
Graphite, 7 pp.
Hair, 7 pp.
Hair Manufactures.
Hats, 26 pp. 26 figs.
Honey. Hops.
Horn.
Ice, 10 pp. 14 figs.
Indiarubber Manufactures, 23 pp. 17 figs.
Ink, 17 pp.
Ivory.
Jute Manufactures, 11 pp., 11 figs.
Knitted Fabrics — Hosiery, 15 pp. 13 figs.
Lace, 13 pp. 9 figs.
Leather, 28 pp. 31 figs.
Linen Manufactures, 16 pp. 6 figs.
Manures, 21 pp. 30 figs.
Matches, 17 pp. 38 figs.
Mordants, 13 pp.
Narcotics, 47 pp.
Nuts, 10 pp.
Oils and Fatty Substances, 125 pp.
Paint.
Paper, 26 pp. 23 figs.
Paraffin, 8 pp. 6 figs.
Pearl and Coral, 8 pp.
Perfumes, 10 pp.
Photography, 13 pp. 20 figs.
Pigments, 9 pp. 6 figs.
Pottery, 46 pp. 57 figs.
Printing and Engraving, 20 pp. 8 figs.
Rags.
Resinous and Gummy Substances, 75 pp. 16 figs.
Rope, 16 pp. 17 figs.
Salt, 31 pp. 23 figs.
Silk, 8 pp.
Silk Manufactures, 9 pp. 11 figs.
Skins, 5 pp.
Small Wares, 4 pp.
Soap and Glycerine, 39 pp. 45 figs.
Spices, 16 pp.
Sponge, 5 pp.
Starch, 9 pp. 10 figs.
Sugar, 155 pp. 134 figs.
Sulphur.
Tannin, 18 pp.
Tea, 12 pp.
Timber, 13 pp.
Varnish, 15 pp.
Vinegar, 5 pp.
Wax, 5 pp.
Wool, 2 pp.
Woollen Manufactures, 58 pp. 39 figs.

SECOND EDITION,

Crown 8vo, cloth, with illustrations, 5s.

WORKSHOP RECEIPTS.

FIRST SERIES.

SYNOPSIS OF CONTENTS.

Alloys
Bleaching
Bookbinding
Bronzing
Candle-making
Cements and Lutes
Cleansing
Crayons
Drawings
Dyeing
Electro-plating
Engraving
Etching
Explosives
Fireworks
Fluxes
Fulminates
Glass
Graining
Gunpowder
Iron & Steel Tempering
Lathing and Plastering
Marble Working
Painting
Paper
Paper-hanging
Papier-Mâché
Pavements
Photography
Plating
Polishing
Pottery
Recovering Waste Metal

Crown 8vo, cloth, 485 pages, with illustrations, 5*s*.

WORKSHOP RECEIPTS,

SECOND SERIES.

SYNOPSIS OF CONTENTS.

Acidimetry and Alkalimetry.
Albumen.
Alcohol.
Alkaloids.
Baking-powders.
Bitters.
Bleaching.
Boiler Incrustations.
Cements and Lutes.
Cleansing.
Confectionery.
Copying.
Disinfectants.
Dyeing, Staining, and Colouring.
Essences.
Extracts.
Fireproofing.
Gelatine, Glue, and Size.
Glycerine.
Gut.
Hydrogen peroxide.
Ink.
Iodine.
Iodoform.
Isinglass.
Ivory substitutes.
Leather.
Luminous bodies.
Magnesia.
Matches.
Paper.
Parchment.
Perchloric acid.
Potassium oxalate.
Preserving.

Pigments, Paint, and Painting: embracing the preparation of *Pigments*, including alumina lakes, blacks (animal, bone, Frankfort, ivory, lamp, sight, soot), blues (antimony, Antwerp, cobalt, cæruleum, Egyptian, manganate, Paris, Péligot, Prussian, smalt, ultramarine), browns (bistre, hinau, sepia, sienna, umber, Vandyke), greens (baryta, Brighton, Brunswick, chrome, cobalt, Douglas, emerald, manganese, mitis, mountain, Prussian, sap, Scheele's, Schweinfurth, titanium, verdigris, zinc), reds (Brazilwood lake, carminated lake, carmine, Cassius purple, cobalt pink, cochineal lake, colcothar, Indian red, madder lake, red chalk, red lead, vermilion), whites (alum, baryta, Chinese, lead sulphate, white lead—by American, Dutch, French, German, Kremnitz, and Pattinson processes, precautions in making, and composition of commercial samples—whiting, Wilkinson's white, zinc white), yellows (chrome, gamboge, Naples, orpiment, realgar, yellow lakes); *Paint* (vehicles, testing oils, driers, grinding, storing, applying, priming, drying, filling, coats, brushes, surface, water-colours, removing smell, discoloration; miscellaneous paints—cement paint for carton-pierre, copper paint, gold paint, iron paint, lime paints, silicated paints, steatite paint, transparent paints, tungsten paints, window paint, zinc paints); *Painting* (general instructions, proportions of ingredients, measuring paint work; carriage painting—priming paint, best putty, finishing colour, cause of cracking, mixing the paints, oils, driers, and colours, varnishing, importance of washing vehicles, re-varnishing, how to dry paint; woodwork painting).

Crown 8vo, cloth, 480 pages, with 183 illustrations, 5*s*.

WORKSHOP RECEIPTS,

THIRD SERIES.

Uniform with the First and Second Series.

SYNOPSIS OF CONTENTS.

Alloys.	Iridium.	Rubidium.
Aluminium.	Iron and Steel.	Ruthenium.
Antimony.	Lacquers and Lacquering.	Selenium.
Barium.	Lanthanum.	Silver.
Beryllium.	Lead.	Slag.
Bismuth.	Lithium.	Sodium.
Cadmium.	Lubricants.	Strontium.
Cæsium.	Magnesium.	Tantalum.
Calcium.	Manganese.	Terbium.
Cerium.	Mercury.	Thallium.
Chromium.	Mica.	Thorium.
Cobalt.	Molybdenum	Tin.
Copper.	Nickel.	Titanium.
Didymium.	Niobium.	Tungsten.
Enamels and Glazes.	Osmium.	Uranium.
Erbium.	Palladium.	Vanadium.
Gallium.	Platinum.	Yttrium.
Glass.	Potassium.	Zinc.
Gold.	Rhodium.	Zirconium.
Indium.		

Electrics.—Alarms, Bells, Batteries. Carbons, Coils, Dynamos, Microphones, Measuring, Phonographs, Telephones, &c., 130 pp., 112 *illustrations*.

WORKSHOP RECEIPTS,

FOURTH SERIES,

DEVOTED MAINLY TO HANDICRAFTS & MECHANICAL SUBJECTS.

250 Illustrations, with Complete Index, and a General Index to the Four Series, 5s.

Waterproofing — rubber goods, cuprammonium processes, miscellaneous preparations.

Packing and Storing articles of delicate odour or colour, or a deliquescent character, liable to ignition, apt to suffer from insects or damp, or easily broken.

Embalming and Preserving anatomical specimens.

Leather Polishes.

Cooling Air and Water, producing low temperatures, making ice, cooling syrups and solutions, and separating salts from liquors by refrigeration.

Pumps and Siphons, embracing every useful contrivance for raising and supplying water on a moderate scale, and moving corrosive, tenacious, and other liquids.

Desiccating—air- and water-ovens, and other appliances for drying natural and artificial products.

Distilling—water, tinctures, extracts, pharmaceutical preparations, essences, perfumes, and alcoholic liquids.

Emulsifying as required by pharmacists and photographers.

Evaporating—saline and other solutions, and liquids demanding special precautions.

Filtering—water, and solutions of various kinds.

Percolating and Macerating.

Electrotyping.

Stereotyping by both plaster and paper processes.

Bookbinding in all its details.

Straw Plaiting and the fabrication of baskets, matting, etc.

Musical Instruments—the preservation, tuning, and repair of pianos, harmoniums, musical boxes, etc.

Clock and Watch Mending—adapted for intelligent amateurs.

Photography—recent development in rapid processes, handy apparatus, numerous recipes for sensitizing and developing solutions, and applications to modern illustrative purposes.

Crown 8vo, cloth, with 373 illustrations, price 5s.

WORKSHOP RECEIPTS,

FIFTH SERIES.

Containing many new Articles, as well as additions to Articles included in the previous Series, as follows, viz. :—

Anemometers.
Barometers, How to make.
Boat Building.
Camera Lucida, How to use.
Cements and Lutes.
Cooling.
Copying.
Corrosion and Protection of Metal Surfaces.
Dendrometer, How to use.
Desiccating.
Diamond Cutting and Polishing. Electrics. New Chemical Batteries, Bells, Commutators, Galvanometers, Cost of Electric Lighting, Microphones, Simple Motors, Phonogram and Graphophone, Registering Apparatus, Regulators, Electric Welding and Apparatus, Transformers.
Evaporating.
Explosives.
Filtering.
Fireproofing, Buildings, Textile Fabrics.
Fire-extinguishing Compounds and Apparatus.
Glass Manipulating. Drilling, Cutting, Breaking, Etching, Frosting, Powdering, &c.
Glass Manipulations for Laboratory Apparatus.
Labels. Lacquers.
Illuminating Agents.
Inks. Writing, Copying, Invisible, Marking, Stamping.
Magic Lanterns, their management and preparation of slides.
Metal Work. Casting Ornamental Metal Work, Copper Welding Enamels for Iron and other Metals, Gold Beating, Smiths' Work.
Modelling and Plaster Casting.
Netting.
Packing and Storing. Acids, &c.
Percolation.
Preserving Books.
Preserving Food, Plants, &c.
Pumps and Syphons for various liquids.
Repairing Books.
Rope Tackle.
Stereotyping.
Taps, Various.
Tobacco Pipe Manufacture.
Tying and Splicing Ropes.
Velocipedes, Repairing.
Walking Sticks.
Waterproofing.

In demy 8vo, cloth, 600 pages and 1420 illustrations, 6s.

FOURTH EDITION.

SPONS'
MECHANICS' OWN BOOK;

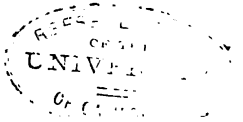
A MANUAL FOR HANDICRAFTSMEN AND AMATEURS.

CONTENTS.

Mechanical Drawing—Casting and Founding in Iron, Brass, Bronze, and other Alloys—Forging and Finishing Iron—Sheetmetal Working—Soldering, Brazing, and Burning—Carpentry and Joinery, embracing descriptions of some 400 Woods, over 200 Illustrations of Tools and their uses, Explanations (with Diagrams) of 116 joints and hinges, and Details of Construction of Workshop appliances, rough furniture, Garden and Yard Erections, and House Building—Cabinet-Making and Veneering — Carving and Fretcutting — Upholstery — Painting, Graining, and Marbling — Staining Furniture, Woods, Floors, and Fittings—Gilding, dead and bright, on various grounds—Polishing Marble, Metals, and Wood—Varnishing—Mechanical movements, illustrating contrivances for transmitting motion—Turning in Wood and Metals—Masonry, embracing Stonework, Brickwork, Terracotta and Concrete—Roofing with Thatch, Tiles, Slates, Felt, Zinc, &c.—Glazing with and without putty, and lead glazing—Plastering and Whitewashing — Paper-hanging — Gas-fitting—Bell-hanging, ordinary and electric Systems — Lighting — Warming — Ventilating — Roads, Pavements, and Bridges — Hedges, Ditches, and Drains — Water Supply and Sanitation—Hints on House Construction suited to new countries.

E. & F. N. SPON, Ltd., 125 Strand, London.
New York: SPON & CHAMBERLAIN.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.



YB 5363